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AN ASSESSMENT OF VULNERABILITY OF THREATENED, ENDANGERED, AND AT-RISK SPECIES TO CLIMATE CHANGE AT FORT HUACHUCA, ARIZONA

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Executive Summary

Future climate change is anticipated to result in ecosystem changes, and, consequently many species are expected to become increasingly vulnerable to extinction. This scenario is of particular concern for threatened, endangered, rare, and species at-risk (TER-S) species. The response of species to climate change is uncertain and will be the outcome of complex interactions and processes. Nevertheless, a simple flexible strategy is needed to help integrate climate change into management planning and actions. This assessment uses basic ecological principals to rank individual TER-S species within the Fort Huachuca region according to predicted climate change responses and associated population declines balanced with responses expected to incur resilience or population increases. Further, specific areas of vulnerability, research needs, and management implications as related to climate change are identified for each species. Based solely on predicted response to climate change, northern Mexican gartersnake and Southwestern willow flycatcher are the most vulnerable to declines. Results also suggest that climate change will make management of some TER-S species more difficult. Several critical management areas are identified that can benefit multiple species including fire and fuels, invasive species, natural and artificial waters, and landscape-scale planning. Management planning should be in place that will assist species impacted by extreme events such as prolonged drought, severe wildfires, or intense flooding. We also use the assessment process to identify areas where climate change may present opportunities for management of TER-S species.

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Acknowledgments

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INTRODUCTION

A large number of species are currently imperiled and at risk of extinction if populations continue to decline (Wilcove and Master 2005). Of federal landholdings, those managed by the Department of Defense (DoD) harbor the most endangered or threatened species. They also contain large numbers of species at risk; those that are imperiled but not yet listed by the U.S. Fish and Wildlife Service (USFWS) (NatureServe 2004). These species, also known as TER-S (threatened, endangered, rare, and species at-risk) are an important element of natural resources management. For species that are not listed as federally endangered or threatened, effective and proactive management of species at risk can prevent listing, reduce costs, and protect biodiversity while, at the same time, insuring that military training is not disrupted (NatureServe 2004). Six threatened or endangered terrestrial vertebrate species and one endangered plant species are known to occur or potentially occur at the Fort Huachuca Army Installation in southeastern Arizona (ENRD 2006). Fort Huachuca is also among the top 20 DoD installations for highest numbers of species at risk (NatureServe 2004).

Over the past century, the climate in the southwestern United States has been becoming warmer and drier, and this trend is expected to continue (Field et al. 2007). In fact, this region is projected to be subject to a significant change in climate that will have broad impacts on ecosystems. Because current climate conditions are already physiologically challenging, even small changes can exceed species' tolerances. There is a broad consensus among climate models that conditions will become more extreme (Archer and Predick 2008), which will have consequences for biodiversity. While the exact nature of these consequences is unknown, shifts in species distributions and changes in populations are highly likely. Declining populations and eventual extinction is of increasing concern for species already at high extinction risk that will experience negative impacts from climate change.

Climate change is a new challenge for natural resources managers that has the potential for exacerbating existing management issues while creating new ones. Preservation of biodiversity will be particularly challenging and few strategies have been proposed to guide managers (Lucier et al. 2006). Species assessments of vulnerability or extinction risk are management tools used to help prioritize conservation needs so that actions can be directed in an effective and efficient manner (Glick and Stein 2010). Species can be ranked based on assessment outcome, but implementation of management actions will also be constrained by goals, economics, politics, and feasibility. To include climate change in a vulnerability assessment is a challenging task because the strongest climate change effects are not yet manifest, global carbon and nitrogen cycling are complex, species vary in sensitivity and adaptive capacity, and direct effects on relatively few species have been identified. To ignore climate change is to risk being unable to respond to a biodiversity crisis.

CLIMATE CHANGE ASSESSMENT

PURPOSE

Anticipation of future impacts can help ameliorate those impacts through early intervention, a key factor for balancing ongoing and uninterrupted military operations with cost-effective natural resource management. Resources for management are also limited, thus priority targets and actions need to be identified. This assessment addresses the vulnerability of individual TER-S (threatened, endangered, rare, and species at-risk) species to population declines associated with projected changes in climate at the Fort Huachuca in southeastern Arizona. Species are ranked by anticipated vulnerability and potential management actions are identified based on the specific vulnerabilities identified. Interaction of climate change variables with currently known threats to species is also discussed. Uncertainty for scores based on the availability of information or contradiction in predictions is also provided. Although scores are limited to the region, they are also generally applicable to adjacent lands to Fort Huachuca.

APPROACH

Vulnerability of species to climate change will depend on sensitivity, exposure, and adaptive capacity (Glick and Stein 2010). The vulnerability scoring tool is an attempt to synthesize complex information related to a projected and uncertain future climate into a simple and flexible set of predictions for the direction of population changes. The USDA Forest Service, Rocky Mountain Research Station has created a tool that scores terrestrial vertebrate species based on basic ecology and life history traits that are related to climate. Although it is in an earlier phase of development, we have also designed a similar, but separate, tool predictive of individual plant species' vulnerability.

Basic ecological principles can be used to predict how species will respond to changing climate through changes in the environment or interacting species. We viewed vulnerability as an increased probability of reduced survival or reproduction and resilience as the reverse. Some predictions were based on simple projected increases or decreases in required resources or known response to temperature or moisture. Others were based on the assumption that particular adaptations will be advantageous over others for projected conditions. For example, species with adaptations to cope with fluctuating resources will likely have better survival than species adapted to exploit stable resources, because increased warming is expected to increase variability in climate and, thus, resources. Scores are based on the balance of these predictive traits. Because the same set of traits is applied to all species, this measure of vulnerability can be compared among species. Traits were chosen that were predictive of response to climate-related conditions from currently available information, but could also be applied to multiple species. Thus, the assessment does not represent a full analysis of the expected response of a species to future changes in climate nor does it integrate impacts other than those that are climate related.

Predictions, and scores, are made based on available projections of how climate and related phenomena are expected to change in the region of interest. Unlike the vertebrate species tool, the plant vulnerability tool is integrated with the climate projections and is, thus, restricted to the southwestern U.S. For this assessment we focused on projections within the next 50 years or less. The specific projections used follow this section.

We assessed species at Fort Huachuca listed by the U.S. Fish and Wildlife Service as endangered or threatened. We included additional species that are either proposed for federal listing, federal species of concern, or of high conservation priority for Arizona as identified by the State Wildlife Action Plan (AGFD 2006). We limited this report to terrestrial vertebrate and vascular plants species. Only one plant species on Fort Huachuca is federally listed: the endangered Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*). One species, the willow flycatcher (*Empidonax trailii extimus*), that occurs adjacent to but not on the Fort, was included along with three species for which there are no recent records: the desert massasauga (*Sistrurus catenatus edwardsi*), northern aplomado falcon (*Falco femoralis septentrionalis*), and the black-tailed prairie dog (*Cynomys ludovicianus*). Prioritization and identification of vulnerabilities are presented separately for vertebrates and plants. Details related to the vulnerability tools and how to use them are available elsewhere (see Natural Resources section at the DENIX portal).

PROJECTIONS OF CLIMATE, DISTURBANCE, AND BIOTIC COMMUNITIES

CURRENT AND FUTURE CLIMATE

The current climate at Fort Huachuca is dry with warm summers and mild winters. Rain falls in the summer and winter with the majority (~60%) arriving during summer monsoons for an average annual rainfall of 38 cm (ENRD 2006). There is considerable topographic variation on the Fort and, consequently, a variety of vegetation types and environmental conditions. The Fort has mostly ephemeral streams that only flow during significant precipitation events. The perennial reaches are in Garden and Huachuca Canyons, though there are minor perennial reaches elsewhere. Flows are generally lowest in early spring before the summer monsoons arrive. Since 1930, this spring dry period has started earlier and lasted longer. These changes have been attributed to climate factors and to changes in upland vegetation. The major perennial stream in the region is the San Pedro River, which is located outside the Fort boundaries (ENRD 2006).

With increasing levels of CO_2, temperatures are expected to rise in southeastern Arizona. Average annual temperature is expected to increase approximately 2.2°C or 4°F by 2050 (Figure 1, www.climatewizard.org, PRISM group, United States mid-century, 12km resolution, downscaling based on Maurer et al. 2007). Projections for precipitation are more varied. In one set of models, projections for winter rain (December-February) are approximately unchanged for 2050 under the current emissions rate and averaged circulation models (Figure 1, www.climatewizard.org, PRISM group, United States mid-century, 12km resolution, downscaling based on Maurer et al. 2007). However, even with no change in rainfall, predicted higher temperatures, will increase evaporation which will result in less available moisture for plants and animals. Other studies predict drying in the Southwest driven by changes in humidity and atmospheric circulation (Seager et al. 2007). In addition, periodic La Niña conditions are associated with severe and prolonged droughts, a fact that is particularly concerning when considered in conjunction with general drying in the region (Seager et al. 2007, Cook et al. 2009). Predictions for summer monsoon rains, however, are currently problematic (Mitchell et al. 2002).

Disturbance

As the climate changes, greater flood risk from more intense storms is projected for the southwestern United States (Garfin and Lenart 2007, Seager et al. 2007). Precipitation falling in intense rainfall events can decrease water available for mesic environments, while these events may increase soil water availability for xeric ones (Knapp et al. 2008), which adds to the problems associated with predicting species' response to climate change.

Wildfires are expected to become more frequent with projected increases in temperature (Rogers and Vint 1987, Swetnam and Betancourt 1990, Esser 1992, Westerling et al. 2006). In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence as years of high rainfall are followed by dry/hot years creating conditions conducive both to ignition and fuel accumulation (McLaughlin and Bowers 1982).

Biotic Communities

Lower elevations at Fort Huachuca are dominated by Chihuahuan desert scrublands and open scrub-grasslands (ENRD 2006). Higher elevations are primarily Madrean oak and oak-pine woodlands (ENRD 2006). Riparian deciduous forest and montane conifer are also present and although they cover a relatively small area of Fort Huachuca, these vegetation types are important to regional biodiversity. Future vegetation will depend on the quantity and season of precipitation, which is currently not well modeled, as well as the interaction of other factors such as fire, grazing, soils, and topography (McPherson and Weltzin 2000). Regardless, climate change is likely to result in widespread disruption of present biotic communities (Figure 1, Rehfeldt et al. 2006).

The relative dominance of shrubs (primarily C_3) versus grasses (primarily C_4) with climate change remains uncertain (McPherson and Weltzin 2000). C_3 shrubs are favored by increases in CO_2 and grazing and may be expected to remain dominant in many areas where they are already established (Archer et al. 1995). Alternatively, C_4 grasses may be favored by increases in temperature and more frequent fire occurrence (Esser 1992). Greater variability in rainfall as predicted by increases in extreme weather conditions (Seager et al. 2007) may induce recurring shifts between grasslands and shrublands, although shrubs will take longer to reestablish after disturbance. Based on warmer temperatures and fire frequency, we assumed grasslands would expand in the next 50 years for this assessment. Expansion of desert scrub is also projected (Figure 1). Summer rains are not well projected, but are particularly important to annuals and succulents, while woody plants tend to rely on winter precipitation (Ehleringer et al. 1991). Future vegetation trajectories will likely also depend on current vegetation, which in turn has been influenced by the heavy grazing that occurred in the past. For example, areas with greater quantities of fine fuel species such as grasses will be more prone to fire and a continued grassland trajectory, while more sparsely vegetated scrublands will be prone to periodic shrub die-offs during drought conditions.

Fire regimes in the region have also been altered by introduced grasses, particularly African species; a process that is likely to continue. One of these species, Lehmann's lovegrass (*Eragrostis lehmanniana*), is already common on portions of the Fort (ENRD 2006). Buffelgrass (*Pennisetum ciliare*), also responsible for changing fire regimes, has not yet been documented on Fort Huachuca, but occurs within at least a 100 km radius around nearby Tucson (Van Devender and Dimmitt 2006). Spread of African grasses, along with increased fires, will encourage further conversion of native habitats to non-native grasslands. While CAM plants, such as cactus and agaves, will be resilient to increasing hot and dry conditions (Smith et al. 1986), they are prone to increased mortality with increasing fires (Thomas 2006), and frequent burning can harm agave seedlings and encourage Lehmann's lovegrass (Robinett 1994).

Riparian habitats in the region are predicted to decline due to decreased average stream flows, increased evaporation, and changes to the flood regime (Stromberg et al. 2006, Serrat-Capdevila et al. 2007). In particular, Stromberg et al. (2006) predict a decrease in cottonwood and willow, an increase of mesquite, and no change in salt cedar (*Tamarix* spp.). Comparisons of salt cedar dominated versus cottonwood willow dominated habitats on the San Pedro River indicate that surface flow permanence was the most important determinant of plant species dominance (Lite and Stromberg 2005), thus, with warmer temperatures and continued water table withdrawals (Stromberg et al. 1996), we may expect greater dominance of salt cedar. Ironically, very high water levels have also been associated with declines in willows and cottonwoods on the Colorado River (Laymon and Halterman 1987).

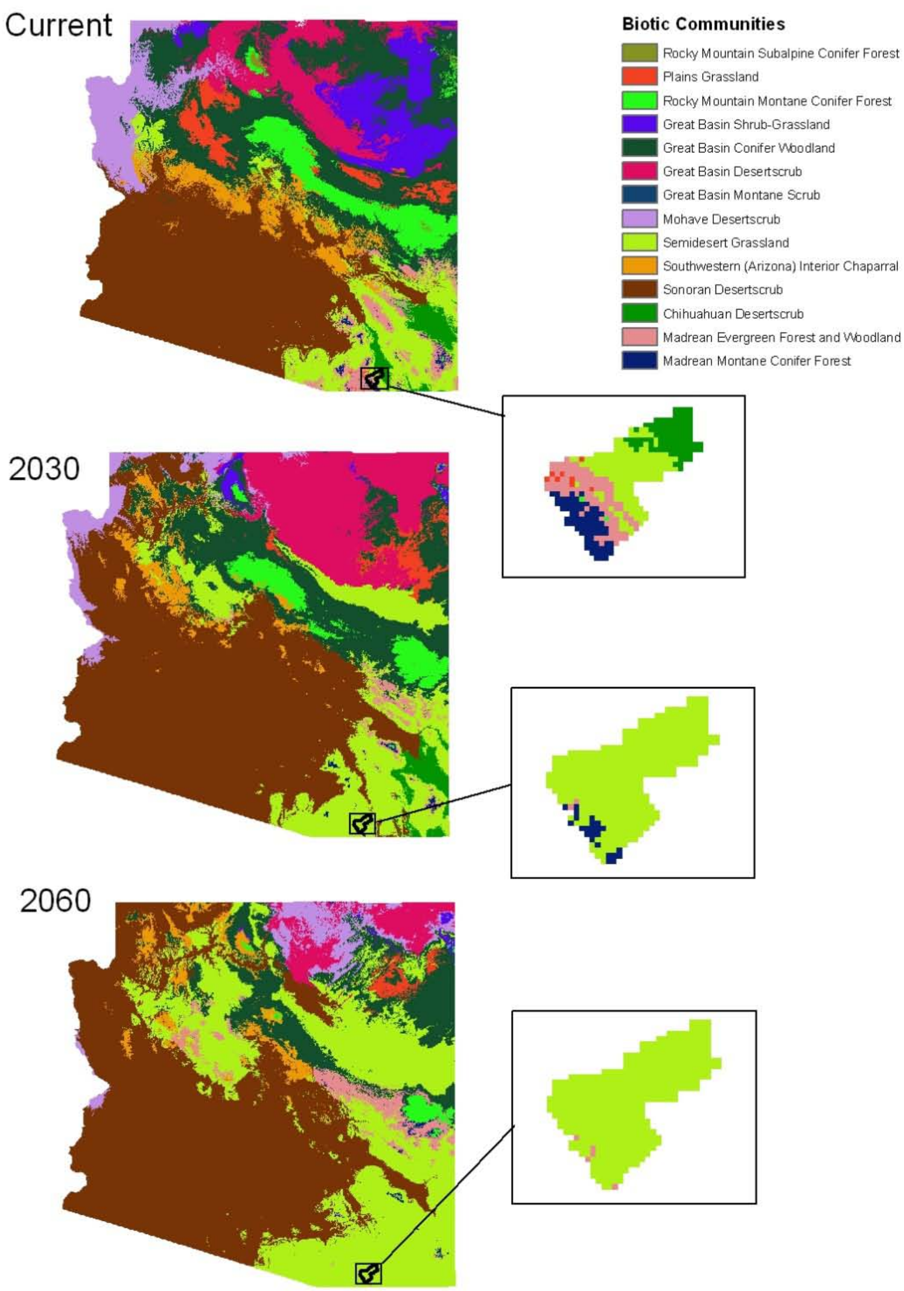

FIGURE 1. CURRENT AND PROJECTED CLIMATE CHANGE AS MODELED FOR THE BIOTIC COMMUNITIES OF ARIZONA. INSET SHOWS FORT HUACHUCA. PROJECTIONS ARE FROM REHFELDT ET AL. 2006. PROJECTIONS WERE USED TO IDENTIFY FUTURE TRENDS FOR BIOTIC COMMUNITIES.

Forest and woodlands types are generally projected to shift upwards in elevation as temperatures warm (Kelly and Goulden 2008, Lenoir et al. 2008). With the relatively small and isolated mountain ranges that occur in this region, upward shifts will inevitably shrink forest habitats. The highest elevations, here montane conifer forest, will be at the greatest risk. The lower elevation Madrean oak and pine-oak communities are also at risk for considerable change. Projections shown in Figure 1, based on Rehfeldt et al. (2006), clearly show the trajectory and future stress on biotic communities with limited Madrean woodlands and no coniferous forest by 2060. These projections, however, are of future climate correlated with the current environment in which biotic communities occur, which cannot capture the fundamental niche of all species nor their complex ecological relationships. Thus, we viewed these projections as trends (i.e., less forest) rather than as the ultimate spatial extent of future communities.

MEXICO AND, CENTRAL AND SOUTH AMERICA

A number of species in this assessment, primarily birds, migrate long distances and are subject to changing climate in distant regions.

Much of Mexico also has a monsoonal precipitation pattern, but annual rainfall is considerably higher to the south than in the border area near Arizona and New Mexico (Comrie and Glenn 1998). Projecting changes in the climate in Mexico is difficult because many General Circulation Models (GCMs) are unable to adequately describe the current climate. Examining a number of models, it is clear that temperatures will increase for all times of year and most dramatically in northern parts of Mexico. Modeling precipitation is less certain, but most models predict reduced annual and summer rainfall with higher temperatures that will exacerbate drying through evaporation (Liverman and O'Brien 1991). At least currently, monsoons are generally asynchronous between northern to central Mexico and the Southwest borderlands (Comrie and Glenn 1998).

Increases in temperature have also been projected for Central America and while precipitation projections are again more variable, most models indicate reduced rainfall in wet and dry seasons (Magrin et al. 2007). Dry periods are also projected to become more extreme and accompanied by increases in extreme events including intense rain, flooding, and hurricanes (Magrin et al. 2007). Central America is also at high risk for forest loss associated with increasing temperatures (Scholze et al. 2005). Increases in temperature may lead to conversion of semi-arid regions to arid and the shifting of high-elevation pine and pine-oak forests upslope. Increases in fire, resulting from increased temperatures and more variable rainfall, will reduce some tree species such as oaks and sycamores although mature pines should be resistant to all but high severity fires.

Towards the southern part of South America, the climate is projected to become more suitable for tropical vegetation, but towards the north, the climate is projected to become drier (Magrin et al. 2007). Wildfires are also expected to increase in frequency. In northern South America, it is projected that tropical forests will be replaced by savannahs (Magrin et al. 2007). Mangroves and other coastal habitats are vulnerable to sea level rise throughout the region (Magrin et al. 2007).

Scoring Results

Vertebrate Species

Twenty-one vertebrate species were scored for Fort Huachuca, Arizona. The highest score, or the species most vulnerable to population decline, was the northern Mexican gartersnake (*Thamnophis eques megalops*) followed by the Southwestern willow flycatcher (Table 1). Species with the highest vulnerability tended to be vulnerable across multiple factors rather than have many predictors of vulnerability within a single factor. The lowest score was for the black-tailed prairie dog, the only species with a negative score, indicating a prediction of more favorable conditions and potentially increasing populations if other threats are not present. The aplomado falcon had the second lowest score, but at 1.2, we expect relative neutrality to climate change conditions in this region. Scores do not directly translate to linear population projections, because we do not know the relative importance of each trait considered nor could every possible predictor of population response to climate change be included. However, the score is the balance of traits associated with vulnerability minus those associated with resilience, thus the score indicates the overall predicted direction of change while the magnitude is an indication of how far the balance is skewed towards vulnerable (positive) or resilient (negative) traits.

Almost all species scored were vulnerable rather than resilient to climate change. It is likely that this result is partly due to climate change exacerbating some of the current impacts already responsible for declines in these species. Although calculation of scores is such that possible negative and positive scores are equal, there could be some other bias in scoring such as a tendency of the scorer to favor vulnerability scores or some inherent factor in the system that biases it towards vulnerable (positive) scores.

Not surprisingly given that grasslands are expected to expand in the region, grassland species tended to be assessed as more resilient. Riparian and high mountain species had some of the highest scores and their habitats are also vulnerable, particularly in the Southwest. It is clear that climate change exacerbates habitat threats that are already implicated in species declines such as the loss of habitats vulnerable to fire or subject to water withdrawals. Importantly, even where habitats were expected to expand, overall scores still sometimes favored vulnerability because of the diverse criteria used to score vulnerability.

Phenology was consistently an important factor in vulnerability for many species. The phenology factor score reflects the relative influence of climate on species' phenology, timing of resources, and the potential for timing flexibility. Ultimate outcome of these relationships is difficult to project, because synchronicity of species to resources can depend on the degree of timing shifts from multiple elements.

Amphibians (average = 6.2) and reptiles (average = 7.0) had the highest vulnerability on average while vulnerability of birds was lower (average = 4.5). This trend exists despite recognition in the scoring system of metabolic resilience of ectotherms. Mammals, on average, were the least vulnerable (average = 2.7) with the Arizona shrew (*Sorex arizonae*) the most vulnerable mammal (Table 1). The more striking pattern, however, is that related species did not group together in the assessment and taxonomic group members are scattered throughout the scores. For example, the three reptile species assessed, all snakes, ranged from 2.2 to 10.8. Bird species were both near the top and near the bottom of the list. More ecologically similar species were similarly vulnerable as exemplified by the two nectivorous bats, the lesser long-nosed (*Leptonycteris yerbabuenae*) and the Mexican long-tongued (*Choeronycteris mexicana*).

TABLE 1. CLIMATE CHANGE VULNERABILITY SCORES FOR THREATENED, ENDANGERED, AND AT RISK TERRESTRIAL VERTEBRATE SPECIES AT FORT HUACHUCA, ARIZONA FROM MOST VULNERABLE (POSITIVE SCORES) TO MOST RESILIENT (NEGATIVE SCORES). POSSIBLE SCORES RANGE FROM -20 TO 20 FOR OVERALL AND -5 TO 5 FOR EACH FACTOR. UNCERTAINTY IS A PERCENTAGE OF SCORING QUESTIONS WITH LIMITED INFORMATION OR CONTRADICTORY PREDICTIONS. FULL SCORING AND SCIENTIFIC NAMES ARE AVAILABLE IN APPENDIX A.

Species	Habitat	Physiology	Phenology	Interactions	**Overall Score**	Uncertainty (%)
Northern Mexican gartersnake	2.9	2.3	2.5	3.0	**10.8**	27.0
Southwestern willow flycatcher	2.7	1.7	3.8	2.0	**9.9**	36.0
Arizona treefrog	3.6	0.7	2.5	1.0	**8.0**	23.0
Arizona ridge-nosed rattlesnake	2.1	1.5	3.8	1.0	**8.0**	41.0
Chiricahua leopard frog	2.7	0.7	2.1	1.0	**6.8**	9.0
Arizona shrew	2.1	2.5	1.3	0.0	**6.4**	55.0
Western yellow-billed cuckoo	1.3	2.5	3.8	-1.0	**6.1**	45.0
Buff-breasted flycatcher	1.3	0.8	3.8	0.0	**5.3**	41.0
Mexican spotted owl	1.3	0.8	2.5	1.0	**5.3**	27.0
Sonoran tiger salamander	2.1	-0.3	2.1	1.0	**5.0**	45.0
Western barking frog	2.1	0.5	2.1	0.0	**5.0**	14.0
Mexican long-tongued bat	1.3	0.7	0.8	1.0	**4.1**	27.0
Elegant trogon	2.0	-1.2	3.8	0.0	**4.1**	32.0
Peregrine falcon	-0.1	0.8	2.5	1.0	**3.5**	23.0
Lesser long-nosed bat	0.5	0.7	0.8	1.0	**3.1**	9.0
Bald eagle	1.3	0.8	-0.4	0.0	**2.4**	23.0
Northern goshawk	1.3	-1.0	2.5	0.0	**2.4**	27.0
Cave myotis	-1.1	-0.2	3.8	1.0	**2.2**	32.0
Desert massasauga	-1.8	1.5	3.8	0.0	**2.2**	41.0
Aplomado falcon	-2.6	0.8	2.5	2.0	**1.2**	23.0
Black-tailed prairie dog	-2.5	-1.0	2.5	0.0	**-2.4**	23.0

The four endangered species, the southwestern willow flycatcher, the lesser long-nosed bat, the aplomado falcon (*Falco femoralis septentrionalis*), and the Sonoran tiger salamander (*Ambystoma tigrinum stebbinsi*), are the ones with the most legal protection, but were not all the most vulnerable. Those species currently considered at increased risk of extinction, but without federal protection may be of particular interest to managers. Several species designated as at-risk or currently in review by USFWS were also identified as vulnerable to declines associated with climate change including the top listed northern Mexican gartersnake (Figure 2).

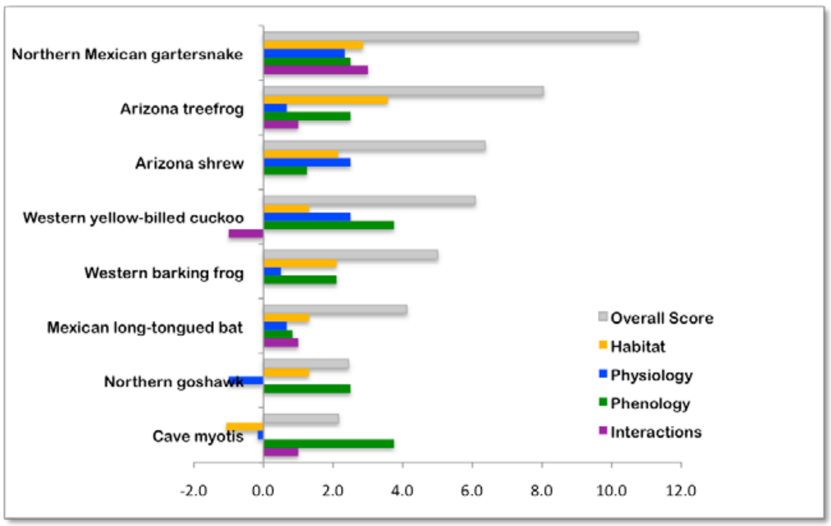

FIGURE 2. VULNERABILITY FACTOR AND OVERALL SCORES FOR FEDERAL CANDIDATE SPECIES OR FEDERAL SPECIES OF CONCERN AT FORT HUACHUCA.

VASCULAR PLANTS

Only two species were assessed, one endangered and the other a candidate for listing. Both received almost identical scores that indicated greater vulnerability with climate change (Table 2). Although population responses may ultimately be similar, these species were vulnerable for very different reasons. The Huachuca water umbel will be exposed to greater drying of its required wetland and riparian habitats, but its ability to disperse via rhizomes and with floods may give it some advantage under projected changes. It is also thought that rhizomes are resistant to drought, although this will depend on drought duration and/or severity. Assessing vulnerability for Lemmon Fleabane (*Erigeron lemmonii*) was limited by lack of information. Although conditions in Scheelite Canyon were expected to remain suitable into the near future, this species also seems to possess few attributes that could be considered resilient. Pollination and reproduction, as for many species, is vulnerable as insects will also be subject to changing conditions resulting in changes in timing and/or numbers.

TABLE 2. CLIMATE CHANGE VULNERABILITY SCORES FOR THREATENED AND ENDANGERED PLANT SPECIES AT FORT HUACHUCA, ARIZONA FROM MOST VULNERABLE (POSITIVE SCORES) TO MOST RESILIENT (NEGATIVE SCORES). POSSIBLE SCORES RANGE FROM -10 TO 10 FOR OVERALL AND -3 TO 3 FOR EACH FACTOR. UNCERTAINTY IS A PERCENTAGE OF SCORING QUESTIONS WITH LIMITED INFORMATION OR CONTRADICTORY PREDICTIONS. FULL SCORING AND SCIENTIFIC NAMES ARE AVAILABLE IN APPENDIX A.

Species	Habitat	Physiology	Interactions	**Overall Score**	Uncertainty (%)
Lemmon fleabane	-0.3	2	1	**2.9**	60
Huachuca water umbel	0.5	1	1	**2.8**	30

MANAGEMENT IMPLICATIONS: USING ASSESSMENT RESULTS

This assessment seeks to help clarify the threat of climate change to individual species and identify potential management actions. Management of TER-S species, however, is not exclusively based on vulnerability nor is climate change the only potential threat to species. Feasibility, economics, and political considerations all play a role in management decisions, but are outside the scope of this assessment. Other aspects of prioritization such as population trends or genetic uniqueness are also factors (Given and Norton 1993). Management actions are likely to be more effective and targeted if priorities and potential impacts are clear. During scoring, we kept our focus on the coming decades that, while more conservative than longer outlooks, are of more practical use to current management and more projectable. Below, we summarize management themes gleaned from the individual species assessments. These are general implications of the climate change assessment for consideration and not a critique of current management programs.

FIRE, FUELS, AND INVASIVE SPECIES MANAGEMENT

As previously noted, conditions conducive to fire ignition and spread are expected to increase. Because individual species respond differently to fire, those fires that burn very large areas or encourage habitat conversion, particularly to non-native vegetation, are of the most concern from a biodiversity perspective. Of particular concern in this region is the interplay between climate, fire, and invasive grasses, which could degrade habitats for some species such as the lesser long-nosed bat. Other species may benefit from expanding grasslands, but conversion from native to primarily non-native grasses alters ecosystem processes and relationships (D'Antonio and Vitousek 1992, Geiger and McPherson 2005, Van Devender and Dimmit 2006). Changes in grassland fire regimes will also affect adjacent woodland and forest habitats as fires spread and communities shift upward. Thus, habitats for forest species such as Mexican spotted owl and Arizona ridge-nosed rattlesnake may be affected.

Fuel management, either through prescribed burning or mechanical treatment, can be used to help reduce fire severity and spread (Graham et al. 2004). Management that focuses primarily on suppression is often counterproductive as this approach eventually encourages greater fire severity (Minnich and Chou 1997, Stephens and Ruth 2005). Because fires of high severity are also inevitable, plans should be in place to reduce potential impacts from fire-fighting efforts (e.g., back-firing, chemical suppressants) and rehabilitate habitats following fire if needed.

Management of non-native plants, particularly invasive grasses, will also be key as they play a major role in altering fire regimes and can outcompete native grasses and forbs. In addition, measures that prevent introductions and spread will be key and less costly than control measures. Critical areas for control may include locations of known TER-S species or adjacent to habitats with TER-S species, dispersal sources such as along roads, and areas with increased ignition risk.

Artificial and Natural Waters

Artificial waters are widely used in wildlife management in the Southwest, although the benefits and potential negative impacts are not well quantified (Broyles 1995). Regardless, increasing droughts and high temperatures will likely make these water sources critical to many species, not just those that have aquatic life stages. Natural and artificial waters on Fort Huachuca should be evaluated for availability to species under drought conditions. Evaluation should consider substrates, capacity and annual longevity, habitat surroundings, special species requirements, disease transmission, and potential for supplemental inputs. Accordingly, artificial waters may need to be expanded or modified.

Several TER-S species require riparian or aquatic habitats. Management that can maintain water tables and streamflows will be important to these species, but the ability to influence current hydrologic processes is limited and likely to become increasingly difficult. Managing water with climate change includes identifying incompatibilities between human and ecosystem needs (Richter et al. 2003). For some TER-S species in this assessment, drying of waters also presents an opportunity. A number of aquatic breeders, including the Chiricahua leopard frog (*Lithobates chiricahuensis*) and the Sonoran tiger salamander, have been extirpated from permanent water sources by such invasive predators and competitors as fish or American bullfrogs, but they are often more tolerant of drying conditions and are currently restricted to temporary waters. Increasingly intermittent water sources may become more suitable for some species and further enhancements, such as invasive species control measures or creating corridors, can make the most of this situation and allow the critical shift of species from drying habitats to newly suitable ones.

ANTICIPATING SHIFTS IN DISTRIBUTION

Depending on a wide variety of factors, including dispersal ability, physiological thresholds, and vegetation response, populations may shift in distribution as local climate changes. From the perspective of a management unit, these shifts will be observed as a change in numbers regardless of the greater population. Management efforts will be better spent on species that are less able to shift with changing habitats than on those that are disappearing from Fort Huachuca, but increasing elsewhere. Shifting of habitats or populations should also be anticipated for geographically-based protected areas or designated critical habitat. Managers may need to reevaluate the future suitability of current or proposed protected areas. Cave myotis (*Myotis velifer*) roosts in cool and moist caves, and as conditions change so will the locations of suitable caves. Although it is difficult to project what new species may disperse to Fort Huachuca, they may be species that require inclusion in management planning. We identified black-tailed prairie dog as potentially expanding based on climate change resilience, depending on impacts from other sources and dispersal barriers. Birds can also be anticipated to be some of the first to shift. Monitoring can help identify species in the early stages of expansion.

Movements and migrations are partly adaptations to changing conditions, thus species may reduce vulnerability by shifting with climate. To facilitate population shifts, corridors will be an important part of managing species under climate change. It may be necessary in some cases to assist the migration process to prevent extinction. Generally known as assisted migration, individuals are moved to new, presumably favorable, locations outside of their historic range. Costs can be high and the nature of climate change is such that new locations cannot be expected to remain suitable in the longterm. Introduction of species to new regions is also fraught with problems, including disruption of species interactions, hybridization, and unpredictable outcomes (Ricciardi and Simberloff 2009). Translocations that include recent historical range (i.e., reintroductions) eliminate many of these issues, but may be of questionable benefit in the longterm. Conversely, translocations may be beneficial for climate change management as new locations may include more favorable microsites, help reduce risk of stochastic events, or may offer better natural dispersal opportunities. Both plants in this assessment could likely be established at new locations, although questions remain as to the desirability of these actions. Falk et al. (1996) provides guidelines for rare plant reintroductions.

COPING WITH PHYSIOLOGICAL THRESHOLDS

Although physiological limitations may shift species' distributions, they may also result in additional stress manifested as poor survival or reproduction (Bernardo and Spotila 2006). TER-S species are at a particular disadvantage for physiological stress, as their small population size will limit adaptation through natural selection. Although an entire management area can become physiologically unsuitable, it is likely that some favorable microsites will remain, at least for the near future. Besides the management of artificial and natural waters already discussed, managers can take advantage of variation in environmental conditions across the landscape and direct protection or enhancements to favorable microsites. In this assessment, limitations of high heat or low moisture were the most concerning, thus priority should be given to microsites with suitable habitat that are cool and moist, such as north-facing slopes or canyon bottoms. Microsites that provide shade are important to thermoregulation (Walsberg 1993) and management that encourages shade plants could be of benefit to some species. Protection of areas with greater litter accumulation or water-retaining soil types could help species like the Arizona treefrog. Fort Huachuca and surrounding areas have varied topography conducive to diverse microclimates, thus there is good potential to use this strategy. In addition, because drought is a limiting factor for many of these species, it may be best to add drought effects to planning documents and anticipate possible interventions.

Anticipating Shifts in Timing

Phenology is an important aspect of life history and is often sensitive to climate conditions. It also was the most sensitive factor to changes for vertebrate species in this assessment (Table 1) and is a potential issue for plant species that are pollinated or dispersed by animals. Management that is time sensitive, such as restricting activities during breeding of a target species, needs to anticipate that timing will change and restrictions need to track these changes. Although timing of individuals is not readily managed, in some cases, management can affect the timing of resources. An example critical to a number of species in this assessment is the presence and duration of temporary pools.

Prioritization

The apparent vulnerability of TER-S species to climate change highlights the challenges that will face managers. Managers already need to make choices about where to focus resources, but as stresses on species magnify, there will likely be an increasing need to prioritize species, actions, or both. Scores from this assessment can be used to aid decisions by identifying species most vulnerable to the additional impact of climate change and the species' traits associated with vulnerabilities. Species that are expected to be resilient may also require management if they negatively impact TER-S species. Ranks in this assessment are based on the number of predicted vulnerabilities across species for the same set of criteria, but likely do not directly translate to a linear progression of population change because some traits may have threshold effects or may be limiting factors. Obviously predictions of climate and vulnerability are uncertain, but an assessment, even if limited, can provide some input when no other information is available and serve as a starting point for beginning to address species management under climate change.

Landscape Scale Management and Partners

Perhaps one of the greatest challenges for managing species under a future climate is that, with continued greenhouse gas emissions, the future is not a steady state. Most management planning, however, focuses on the next 10 to 20 years and we assessed species with that timeline in mind. Partners will be extremely valuable and managers from adjacent lands will be experiencing similar climate conditions and issues. Management at a landscape scale is well suited for climate change issues, as well as being cost effective. Cooperative approaches can help to balance costs and benefits of competing needs. For example, cooperative monitoring at a large scale can separate population shifts from regional declines and detect newly arriving species early. Fort Huachuca is already part of the Huachuca FireScape, a regional effort to address fuels reduction and a good example of a landscape-scale management plan that can begin to address adaptation to climate change. Similar landscape efforts are needed to address climate change threats to species and related factors, including wildlife corridors, invasive species, water availability, and microsite diversity.

Uncertainty

Although drawn from basic life history and ecology, in many instances, scoring was uncertain because of lack of information. Deficiencies were common in a few key areas for vertebrates, but were more extensive for plant species and limited scoring criteria. For example, physiological thresholds for vertebrates in natural environments are known for few species. More uncertainty is added when scoring depends on a secondary prediction for another species (e.g., predators, pollinators, disease vectors). Although predictions may be limited by information gaps, we felt it was important to include critical relationships of species with climate. As part of scoring, we also used uncertainties to identify research priorities. Predicting the future is inherently uncertain, but the exercise of prediction will improve as better models are developed and more research is done. Scores can be updated as new information becomes available.

Next Steps

Vulnerability and resilience predictions are based on responses that are likely a matter of degree and dependent on the strength or duration of projected changes. This assessment is not meant to substitute for more thorough and complex analyses of climate change response, but those approaches will also be limited in their ability to predict the future. Predictions for plant species were particularly difficult to make using this approach and may be more suitable for modeling based on climate envelope or niche modeling than vertebrate species. The scoring systems used in this assessment are simple and flexible by design. Scores can easily be modified to reflect any future changes in projections, although we suspect these will make little difference to the outcome. Managers are encouraged to apply scoring to additional species or to use their knowledge to modify the scoring of species included here. By focusing on ecology and life history traits, these scoring systems can take advantage of the considerable knowledge of local resource managers rather than depend on expertise in modeling or computer simulations that need to be tailored to particular species or regions.

This assessment can help identify management targets including species and actions. Information from assessments can also be used as part of more complex multi-species or landscape planning such as outlined by Lawson et al. (2008). In addition, this assessment highlights different pathways by which populations can be affected by climate, which is important for initiating dialogue and solutions. Predicting effects on individual species is inherently complex and primarily speculative at this point, but we believe that the need for managers to address climate change is becoming more urgent (Thomas et al. 2004) and that tools, regardless of their limitations, are needed now. While the process and the product are inherently imprecise, this effort is an important first step towards anticipating and responding to climate change and provides a framework for integrating new research and information.

USEFUL INFORMATION SOURCES

Intergovernmental Panel on Climate Change
Climate Wizard
Climate Assessment for the Southwest (CLIMAS)
Denix Portal: Natural Resources
DoD TES document repository at NBII (National Biological Information Infrastructure)
U.S. Forest Service Climate Change Resource Center
Southwest Climate Change Network
NatureServe Climate Change Vulnerability Index
National Phenology Network
Fire Research and Management Exchange System (FRAMES): Southwest
U.S. Drought Monitor

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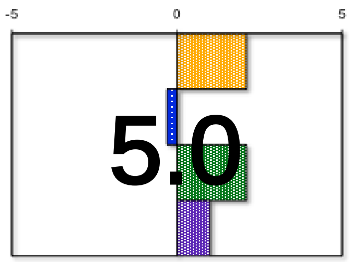
APPENDIX A: SPECIES ACCOUNTS



Sonoran Tiger Salamander
(*Ambystoma tigrinum stebbinsi*)

SUMMARY

Declines in amphibians are associated with interactions of multiple threats and the threat due to climate change is likely to contribute to further vulnerability. Life history strategies, such as having both terrestrial and aquatic life forms, may give this species some resilience to fluctuating rainfall patterns and drought. Unfortunately, this species is already very restricted and is vulnerable to extirpation with fluctuations in habitat suitability.

Introduction

The Sonoran subspecies of tiger salamander is currently listed by the U.S. Fish and Wildlife Service (USFWS) as endangered. No critical habitat has been designated as of the time of this report. It is a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). Known from ponds in the San Rafael Valley, Arizona. Currently, Sonoran tiger salamanders are found mostly in human-made ponds or cattle tanks. Following European settlement, erosion and alterations to the hydrology within the species' range are thought to have destroyed most of the temporary pond habitats. Permanent water, although suitable, often has introduced fish and bullfrogs, which prey on salamanders. Most salamanders on Fort Huachuca are thought to be barred tiger salamanders except for one pond near the San Rafael Valley in the Upper Garden Canyon (USFWS 2002).

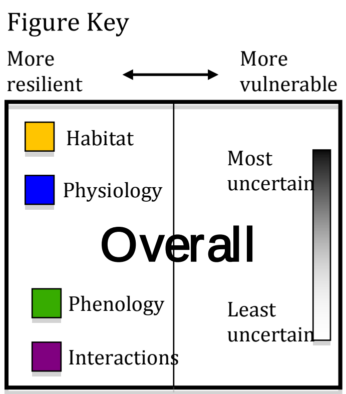
Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.1**	43%
Physiology	**-0.3**	33%
Phenology	**2.1**	50%
Interactions	**1.0**	60%
Overall	**5.0**	45%



Other threats and interactions with climate
Tiger salamanders are threatened by loss of habitat, introduced predators, and hybridization with barred tiger salamanders (USFWS 2002). Threats such as UV radiation, water pH, pesticides, and disease may interact and increase susceptibility to declines. A number of these threats will likely be exacerbated in the future by climate change. Although most threats identified are associated with aquatic habitats, terrestrial habitats may also be vulnerable to drier conditions, which will limit their suitability.

This species is restricted to only a few locations, and introduced predators and barred tiger salamanders, with which it can hybridize, limit dispersal to new locations. Dispersal among aquatic habitats, however, will become increasingly important as these habitats vary in susceptibility to drying. Drought can further disrupt dispersal by removing potential corridors and altering habitat suitability. Monsoons likely play a role in providing dispersal opportunities, but are not well projected for the future. It is likely that monsoon rainfall will become more variable so dispersal opportunity is expected to likewise fluctuate widely from year to year.

Research Needs
Periodic die-offs associated with Ambystoma Tigrinum Virus (ATV) have no known relationship to climate or habitat, but this virus has only been recently identified and little field study has been conducted. Habitat features associated with favorable terrestrial habitats have received little attention. An assessment related to future condition of wetlands and dispersal corridors will be important to identifying suitable habitat of the future and planning management.

Management Implications
Management related to maintaining water tables and pond duration is important. The only known population on Fort Huachuca occurs in an artificial pond. This pond has shrunk and even dried in past years, but the population has survived these episodes (ENRD 2006). Longer dry periods, however, will likely be detrimental, though critical limits are not known for the species. Although options for this particular pond are unknown, some ponds may be suitable for artificial water inputs should they dry for too long a period. Additionally, factors related to tank construction and pond substrates can likely be used to increase water retention of ponds. Attention should also be given to protection of terrestrial habitats adjacent to temporary ponds used by terrestrial salamanders. Litter and debris as well as low levels of disturbance are likely important factors that can be managed to maintain favorable microclimate of these habitats.

Currently occupied habitats are those that dry periodically to discourage non-native predators and competitors while still staying moist enough to allow survival of larval salamanders. These areas will be subject to further drying that can eventually make them unsuitable. Some areas that currently sustain permanent waters may actually increase in suitability as drying occurs and aquatic non-natives are extirpated. Dispersal will then be critical to survival in the future. Removal of barred tiger salamanders and introduced fish from suitable dispersal habitats could also be implemented to increase available habitats and resiliency of populations to declines. Translocation could be a viable option for future management of this species and should be planned based on predicted future wetland conditions along with potential for increased predation.

Habitat: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Terrestrial adults live in oak woodlands and grasslands (USFWS 2002). Grasslands may expand, but woodlands will be vulnerable to increasing fires and upslope shifts. Overall, no change projected.	**0**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Eggs are laid in water of permanent or temporary sources and attached to vegetation, debris, or rocks (USFWS 2002). Water availability is expected to be reduced.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Terrestrial adults use mammal burrows or bury themselves in soft soils to escape desiccation. Soils suitable for burrows are not expected to change.	**0**

Habitat: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Better survival is associated with more emergent vegetation, some shallow water, and soft substrates (Sarell 2004). Emergent vegetation may be reduced with warmer temperatures and greater evaporation, although this will depend on hydrology of specific sites.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Little information on site fidelity, but other congeneric salamanders generally return to the ponds where they were born. Dispersal has been observed up to 3-4 km from source populations (USFWS 2002). Others note that tiger salamanders have a minimal capacity for dispersal and they usually migrate 162m to 229m from breeding pond to aestivation sites over 3 days (AmphibiaWeb 2008). Dispersal is also thought to be limited by distribution of temporary ponds. Overall, limited ability to disperse as habitats change.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Moves between terrestrial and aquatic environments, but no specific transitory habitats required.	**0**

Physiology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Eggs are prone to freezing and dehydration (USFWS 2000). Adults are tolerant temperature from 5°C to 30°C in ponds and in terrestrial environments can survive below freezing to above 35°C (USFWS 2002). Terrestrial amphibians are prone to desiccation, which will increase with warmer temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Although floods may occur more frequently along stream courses, currently occupied ponds are not vulnerable to flooding. No effects of fires known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Terrestrial movements are limited by moisture and may be decreased by warmer temperatures and greater evaporation. Aquatic movements probably not be limited.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Mostly adults are terrestrial while larvae are aquatic. Mature individuals can remain aquatic (branchiate adults or neotenes) with gills or metamorphose into gill-less terrestrial adults. Branchiate adults occur in permanent water sources and although pond drying can induce metamorphosis, many branchiate adults die during the process (USFWS 2002). In permanent water, only 17% metamorphose into terrestrial adults, while all that are large enough will in drying ponds (Collins et al. 1988). 200 to 2000 eggs are laid (USFWS 2000) and can have large reproductive output in favorable years.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Temperature is a cue for adult emergence and migration (AmphibiaWeb 2008).	**1**

Phenology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Requires standing water from January through June for aquatic young to develop (USFWS 2002). Rarely breeds after monsoon rains (USFWS 2002). Standing water likely related to timing of winter rainfall, which is likely to change.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Eggs take longer to develop in colder water (USFWS 2002), thus development may keep up with changing pond duration to some extent. Favorable migration conditions directly trigger migration.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Most report one reproductive event per year (Sarell, 2004), though some cite two if habitat is available. However, Church et al. (2007) suggests the latter is prohibitively costly for females.	**1**

Biotic Interactions: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Adults eat a variety of invertebrates. Branchiate adults eat zooplankton and macroinvertebrates. No expected changes in overall prey levels of diverse species.	**0**
2. Predators	Are important predator populations expected to change?	Predation is considered a major threat to this species. Predators included caddis flies, dragonfly naiads, predaceous diving beetles, giant water bugs, newts, conspecifics (cannibalistic morphs), snakes, predatory, wading and shore birds, badgers, raccoons, coyotes, opossums, and humans (AmphibiaWeb 2008). Predators, particularly American bullfrog and introduced fish, pose significant threat and considerable impact on salamanders (USFWS 2002). Currently mostly occupies habitats without fish and few	**1**

Biotic Interactions: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		bullfrogs (USFWS 2002), but impacts from American bullfrogs may increase as they are expected to be resilient to climate change.	
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Frequent disease outbreaks attributed to a ranavirus, ATV (Ambystoma tigrinum virus) (Jancovitch et al. 1997). Frogs and fish could not be artificially infected and are not likely carriers for this disease (Jancovitch et al. 2001). No research was found to indicate that these ranaviruses would increase with warmer temperatures.	**0**
5. Competitors	Are populations of important competing species expected to change?	Fish are not only predators, but also a primary competitor (Sarell, 2004). Fish do not occur in current habitats. Barred salamanders may also compete, but are expected to have similar response to climate change.	**0**

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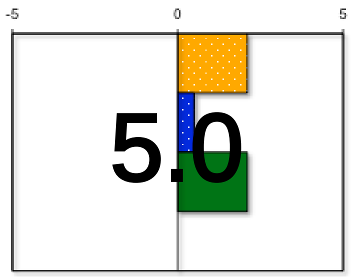


Western Barking Frog
(*Eleutherodactylus augusti cactorum*)

SUMMARY

The barking frog is unusual compared to other frogs in Arizona. They are terrestrial species with direct development of the young from eggs, which also receive parental care. These features, along with its lack of reliance on aquatic habitats, may incur greater resilience to climate change in comparison with some frog species. Conversely, dependence on rainfall and moist habitats along with low dispersal ability will likely increase this species' vulnerability to declines with climate change. Balancing these traits overall, this species was assessed to be vulnerable to declines associated with projected climate change.

Introduction
Populations of Western barking frog were discovered on Fort Huachuca in 2002. It is a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and designated as a species at risk (SWESA 2006). Range in the U.S. is Arizona, New Mexico, and Texas along the Mexico border where the majority of the range occurs (AmphibiaWeb 2010). It is the only representative of this mostly tropical family in Arizona. There is currently unresolved taxonomy for subspecies (AmphibiaWeb 2010) and individuals in Arizona differ from those found in New Mexico and Texas (Goldberg 2003).

Fort Huachuca climate and projections
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

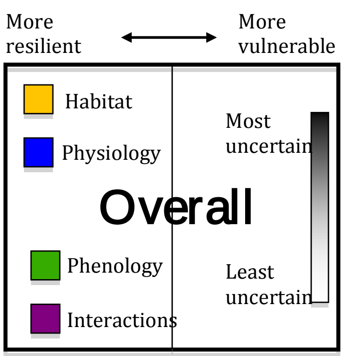
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.1**	14%
Physiology	**0.5**	17%
Phenology	**2.1**	0%
Interactions	**0.0**	20%
Overall	**5.0**	14%

Figure Key



Other threats and interactions with climate

Habitat loss may be the greatest current threat to this species. Open pit copper mining has been implicated in the loss of Arizona habitat (Goldberg 2003), but mining does not occur on or adjacent to Fort Huachuca. Other habitat loss, such as through disturbance, will likely increase with climate change as fires increase and rainfall becomes more variable. Although vegetation associated with this species will be vulnerable to changes, species' presence may be more closely linked to geologic features such as rock outcrops. Association with oak woodlands and mixed pine-oak forests may be more related to moisture than vegetation type. Changes in the amount of rainfall, especially the summer rains that are tied to breeding in this species, is difficult to project, but drier conditions on average seem likely with increased evaporation from higher temperatures and changes in rainfall timing.

Research Needs
Little is known about this species and monitoring populations is difficult because of their cryptic behavior (Goldberg and Schwalbe 2004). Full species' range in Arizona is unknown, because this species may be undetected in additional locations (Goldberg 2003).

Management Implications
This species may be difficult to manage if climate change brings drier conditions. Its association with particular geologic features and low dispersal ability make it unlikely to move upslope or to new locations. It may, however, currently occur in more locations than are known making any assessment of population trends difficult. This species' association with moist habitats rather than permanent waters and ability to remain inactive for extended periods will help it cope with dry years better than many of the semi-aquatic amphibians. Extent of vulnerability in this species will depend on monsoonal rain patterns and drought intensity. Because these climate events are not well projected, management may be best focused on documenting habitat and presence of the species. Planning that includes contingency plans for assisting species during extreme conditions should consider actions to assist this species. Although a controversial method, this species may be a good candidate for localized translocations with transfer from drier locales to more mesic locales.

Habitat: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In Arizona, occupies elevations from 1280 to 1890m (Degenhardt et al. 1996). In Arizona, barking frogs have been found in rock outcrops within Madrean evergreen woodlands (Goldberg and Schwalbe 2004) and pine-oak woodlands (Brennan and Holycross 2006).	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Eggs are laid in moist and protected locations such as rain-filled cracks, fissures, and moist caves or under rocks (AmphibaWeb 2010). Rock outcrops and fissures unlikely to change, (see Physiology Question 3 and Phenology Question 2).	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Winter or dry season refugia are required. Generally associated with cliffs and caves. Rock outcrops and caves are unlikely to change.	**0**

Habitat: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Not known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Very limited movements.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Move between overwintering and summer activity sites up to 50m (AmphibiaWeb 2010). No transitional habitats required.	**0**

Physiology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Although terrestrial, like many amphibians, this species is prone to dessication.	**1**

Physiology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	No known disturbance interactions. Moist rocky habitats are not fire prone. It is speculated that females may stay with the eggs and excrete urine to maintain moisture (Brennan and Holycross 2006, AmphibiaWeb 2010), thus this may help eggs to survive more variable rainfall and drying conditions. Extended droughts likely limit reproduction and survival.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity is limited by moisture. Drier conditions are likely with warmer temperatures.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	May go several years without breeding and then has clutches containing from 50–76 eggs (AmphibiaWeb 2010). Tadpoles develop inside the egg and emerge fully developed. In addition, females may tend the eggs and keep them moist (Brennan and Holycross 2006). These strategies may help this species survive during dry years.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic and may be able to use torpor facultatively (AmphibiaWeb 2010).	**-1**

Phenology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Males generally call with rainfall and in Arizona typically with summer rains beginning in June or July (AmphibiaWeb 2010).	**1**
2. Event timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Breeding coincides with rainfall likely because of moist conditions needed for successful egg laying and development (AmphibiaWeb 2010). Foraging may also be limited by moisture. Timing of rainfall is likely to change.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding appears to be triggered directly by rainfall, which provides required moisture for egg development, thus close match between cues and resources.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event per year.	**1**

Biotic Interactions: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats a variety of invertebrates including grasshoppers, centipedes, and crickets (AmphibiaWeb 2010). Wide variety likely has differing responses to climate change.	**0**
2. Predators	Are important predator populations expected to change?	Unknown predators (AmphibiaWeb 2010).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases. Terrestrial habits likely reduce risk of chytridiomycosis.	**0**
5. Competitors	Are populations of important competing species expected to change?	No known competitors. Very different associations than other local frogs.	**0**

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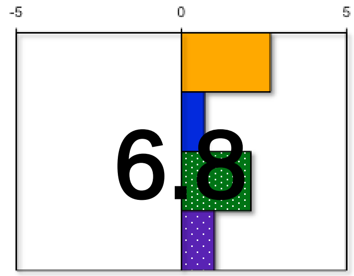


Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)

SUMMARY

Chiricahua leopard frogs remain extant in small, scattered ponds and stock tanks, because larger and more permanent water sources generally contain more native and non-native predators and competitors. Unfortunately, these habitats will be at greater risk to drying as temperatures warm. Conversely, increased temperatures may offer a number of advantages as drying of water sources for short periods can help reduce non-native predators, higher temperatures reduce susceptibility to chytridiomycosis, and warmer waters increase growth rates. Many questions surround prediction of climate change effects in this species because of the complex interaction of threats and climate. Management will be critical, because location of suitable habitats is expected to shift.

Introduction

Genus changed from *Rana* to *Lithobates* (Frost et al. 2006), but *Rana* is still in common use. Chiricahua leopard frog was listed as threatened by U.S. Fish and Wildlife Service in 2002. Populations previously identified as Ramsey Canyon leopard frog (*Rana subaquavocolis*) are now considered a population of the Chiricahua leopard frog (Goldberg et al. 2004, Hillis and Wilcox 2005). Ramsey Canyon leopard frog is designated as a species at risk (SWESA 2006). There are two disjunct metapopulations: montane populations along the Mogollon rim and western New Mexico and southern populations in the border region of Arizona, New Mexico, and Mexico (USWFS 2007). They have disappeared from many of their historic locations and appear be present at less than 20 percent of those sites (USFWS 2007).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

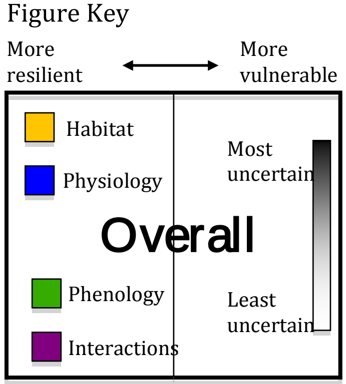
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.7**	0%
Physiology	**0.7**	0%
Phenology	**2.1**	25%
Interactions	**1.0**	20%
Overall	**6.8**	9%

Figure Key



Other threats and interactions with climate
We focus on those impacts expected to interact with climate change and refer the reader to Southwest Endangered Species Act Team 2008 report on this species for a thorough overview of impacts and management recommendations regarding the Chiricahua leopard frog. Also note that the climate change vulnerability score was based on currently occupied habitats and several additional traits would have been considered vulnerable if we had included formerly occupied habitats during scoring. This species is threatened by invasive species, water regulation, mining, fire in upland habitats, pesticides, UV radiation, and chytridiomycosis (USFWS 2007). In

addition, life history predisposes this species to ongoing extirpation and recolonization of populations, thus any disruption of metapopulation dynamics can result in the loss of the species from entire regions (USFWS 2007). Although not currently overlapping with the range of the Chiricahua leopard frog, the Rio Grande leopard frog (*Rana berlandieri*) has been introduced in other parts of Arizona (Platz et al. 1990). Expansion of the larger Rio Grande leopard frog could negatively impact populations. Several of these threats are expected to interact with climate.

Individual localities are subject to extirpation and recolonization with metapopulation dynamics important to longterm persistence. Maintenance of corridors for dispersal of juveniles and adults is thought to be critical to preserving populations (Jennings and Scott 1991, USFWS 2007). Drought can disrupt dispersal by removing potential corridors and altering habitat suitability. Temporary pools that do not support non-native predators may provide the best conditions for dispersal. Monsoons likely play a role in providing dispersal opportunities, but are not well projected for the future. It is likely that monsoon rainfall will become more variable so dispersal opportunity is expected to likewise fluctuate widely from year to year.

Fires, particularly those of high severity, can negatively impact leopard frog populations, particularly through indirect effects via burned upland habitats. Leopard frog habitat is lost or degraded following fire through sedimentation and high run-off events as may have occurred in Miller Canyon following the 1977 wildfire (SWESA 2008). Increased fire occurrence and severity in upland habitats and increased storm intensity are more likely to occur with future climate resulting in an increased risk to Chiricahua leopard frog habitats. Depending on fire season and severity, fire can also have positive impacts through increases in water availability (Neary et al. 2005), but these increases are generally temporary. Chemicals used in fire suppression are toxic to tadpoles and may concentrate in ponds and pools such as those favored by the Chiricahua leopard frog (Calfee and Little 2003).

Research Needs

There are conflicting predictions for the interaction of chytrid fungus and climate change that need to be resolved. Better information is needed on the interactions of chytrid fungus and temperature in effects on disease prevalence and population dynamics as well as important variables such as bullfrogs and water permanence. Local landscape predictions of future wetland distributions will be important to evaluating dispersal and effective management options.

Management Implications

Substrate of water sources, such as those that can maintain wet mud layers, may be important in survival during periods when surface waters dry. Concrete substrates may maintain surface water longer, but would not provide refuge during dry periods. It is these sites that are prone to drying where the species remains extant due to absence of aquatic predators (USFWS 2007), thus management attention to water duration and substrate may be critical with increasing droughts. Monitoring of water sources will be critical during droughts and some locations may be suitable for artificial inputs.

Currently occupied habitats are those that dry periodically to discourage non-native predators and competitors while still staying moist enough to allow survival of leopard frogs. These areas will be subject to further drying that will eventually make them unsuitable. Some areas that currently sustain permanent waters may actually increase in suitability as drying occurs and non-natives are extirpated. Dispersal will then be critical to survival in the future. Translocations could be a viable option for future management of this species and should be planned based on predicted future wetland conditions along with potential for increased predation or incidence of disease.

Reduction of fuels in upland habitats may help reduce negative impacts on downslope leopard frog habitats. Impacts from fire suppression efforts such as construction of fuel breaks or use of fire retardants in areas upstream of leopard frog habitats should be minimized. Placement of straw bales is recommended to protect leopard frog habitats following wildfires (SWESA 2008). These recommendations are not new, but predictions related to future fire occurrence make this a critical planning topic.

Habitat: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Chiricahua leopard frogs are found in wetland habitats in oak, pine forests, and mixed woodlands with some range extensions into chaparral, grassland, and desert habitats at elevations from 1000-2710m (USFWS 2007). They occur in various permanent and near-permanent waters. Wetland habitat area is expected to be reduced in all these associated upland vegetation types.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Adults breed in various natural and human-made still waters including livestock tanks and backyard ponds. Shallow water with emergent vegetation is used for egg laying in adults (USFWS 2007). Waters need to be large enough to sustain tadpoles several months through metamorphosis. Suitable breeding waters are expected to be reduced with greater evaporation from increased temperatures.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Moist locations are required for hibernation. Deeper waters and undercut banks provide escape from predators and potential hibernacula (SWESA 2008). Other leopard frogs hibernate buried in mud of well-oxygenated streams and ponds (USFWS 2007). We assume similar behavior in the Chiricahua leopard frog. Moist locations and deep waters are expected to be reduced.	**1**

Habitat: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Cover provided by vegetation along the water's edge might provide escape from visual predators while increasing presence of other predators such as snakes (SWESA 2008). Shallow water with emergent vegetation is used for thermoregulation in adults (USFWS 2007). Aquatic vegetation that is too dense can be detrimental by reducing water temperatures and availability of basking sites (SWESA 2008). Changes will depend on size and hydrology of current waters, but may increase as larger permanent water sources become more intermittent, warmer, and shallower.	**-1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Temporary pools may be important during movements (SWESA 2008). Based on other ranids in the region, adults can likely move one mile overland, three miles with intermittent water sources, and five miles along permanent waters (USFWS 2007). Dispersal will depend on landscape variables, but low ability to disperse compared to other vertebrates.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Does not require transitional habitats to move between breeding and non-breeding areas.	**0**

Physiology: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Adults are semi-aquatic and larvae are entirely aquatic. Chiricahua leopard frogs occur in hot arid environments of Arizona, New Mexico and Mexico although distribution of species is fragmented by aridity that limits pond habitats (Lannoo 2005). Water temperatures at which eggs have been found in the wild generally range from about 13°C to 30°C (55°F to 85°F) (Zweifel 1968, USFWS 2007). Temperatures not likely to be limiting in aquatic habitats and this species does not occur away from water where it is prone to dessication.	**0**

Physiology: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Periodic drying of individual localities, in part, drives metapopulation dynamics. Jones and Sredl (2005) observed apparent local extirpations that coincided with drought. Extirpation of populations in the Baboquivari Mountains was attributed to drought and drying of stock tanks (USFWS 2007). Species generally breeds away from areas prone to flooding. High severity wildfires have also resulted in extirpation of populations (USFWS 2007). Fires are expected to increase in intensity.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Studies of diurnal surveys indicate that this species is active early in the day and avoids activity during warmer air temperatures (USFWS 2007). May be further limitations to activities during the day.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**0**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Water temperature is likely related to timing of egg laying. Although hibernation has not been studied in this species, adults are generally inactive when water temperature is below 52°F (14° C) from November through February (USFWS 2007). One unpublished report noted that oviposition appeared to be correlated with changes in water temperature, and not precipitation (Lannoo 2005). Supporting this view is the observation that oviposition occurs earlier at lower elevations (Frost and Platz 1983) and Elliott et al. (2009) found that breeding can occur whenever the water temperature exceeds about 57° F (14°C). Uses temperature cues for breeding and hibernation.	**1**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Seasonal activity seems to be limited by temperature with year-round activity and breeding noted at one site in New Mexico with thermal springs (USFWS 2007, SWESA 2008). Egg masses have been reported in all months except November, December, and January (USFWS 2007). Populations previously identified as the Ramsey Canyon leopard frog lay eggs February to November (SWESA 2008). Populations below approximately1800 m generally deposited eggs mostly before June, whereas above 1800m eggs were laid in June, July, and August (Frost and Platz 1983). Expected changes to favorable breeding times.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Work by Jennings found that frogs were most abundant when water temperatures were warmer and more egg masses were found in areas with warmer water, an effect likely related to increased development of tadpoles (SWSAT 2008). Egg hatching and tadpole development are faster in warmer temperatures (Jennings 1990). This may help time breeding to favorable conditions as the cue (water temperature) is directly related to favorable water conditions for egg and tadpole development.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event a year and although breeding can occur during most of the year it generally is limited within a region and few populations breed year round.	**1**

Biotic Interactions: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Larvae are herbivorous and adults eat a diverse array of insects (Degenhardt et al. 1996, USFWS 2007). Christman and Cummer (2005) examined stomach contents of museum specimens and found the majority to be aquatic and terrestrial invertebrates. Changes in invertebrates are expected to be species specific. Larvae eat algae, which may increase with warmer waters although too much algae removes oxygen. Based on mixed predictions, no overall effect is predicted.	**0**
2. Predators	Are important predator populations expected to change?	There are a large variety of predators for larvae and adults. Juvenile and adult frogs are likely preyed upon by fish (native and non-native), American bullfrogs, garter snakes, birds, variety of mammals (Lannoo 2005). Presence of American bullfrogs, crayfish, and predatory fish are negatively correlated with presence of this species (USFWS 2007). Although these non-natives are expected to be resilient to climate change, this species currently only occupies habitats where they are not present. No change in exposure to predation expected in current locations.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Chytridiomycosis has been identified in populations of the Chiricahua leopard frog including some from those previously identified as Ramsey Canyon leopard frog (USFWS 2007). In late 1980s, high mortality of this species in earthen cattle tanks in New Mexico was observed and "post-metamorphic death syndrome" was implicated although chytrid fungus may have played a role (Lannoo 2005). Although implicated in declines in numerous amphibian species including this one, there are also cases where this species is coexisting with this disease, thus infection may act synergistically with other stressors (USFWS 2007). In Arizona, die-offs of ranids are correlated with cooler months (Bradley et al. 2002). Survival of frogs with chytrid infection is improved at sites with warmer waters (USFWS 2007). American bullfrogs, which are important reservoirs for the disease, however, are expected to be resilient to climate change increasing transmission rates as limited water sources become more crowded. Although increase of susceptibility of amphibians to chytrid fungus with climate change remains controversial, in this case rather than predicting a decreased mortality, because of the effect of warmer waters, we feel any positive effect will be counterbalanced with increased transmission and	**0**

Biotic Interactions: Chiricahua Leopard Frog (*Lithobates or Rana chiricahuensis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		potentially synergistic effects with other stressors related to greater variability in rainfall.	
5. Competitors	Are populations of important competing species expected to change?	Current range is considered limited by presence of non-native predators such as crayfish, bullfrogs, and fish (USFWS 2007). American bullfrog tadpoles reduce algae food resources available for leopard frog tadpoles (Boone et al. 2004). Although competition with non-natives is currently low in habitats occupied, we do expect competition with larvae or tadpoles of other amphibians such as tiger salamander to increase as wetland areas shrink.	**1**

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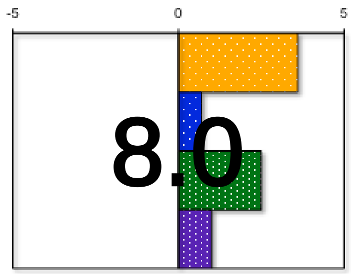


Arizona treefrog
(*Hyla wrightorum*)

SUMMARY

Threats related to habitat for the Arizona treefrog will likely increase with projected climate change. In addition, small population size and isolation from other populations will intensify extinction risk. Conversely, reduced rainfall and increased temperatures will threaten important temporary waters, but may increase suitability of some currently permanent waters by creating more intermittent reaches. Reproductive failure from alteration of monsoon timing is additionally a concern. Potential benefits are likely to be overshadowed by the large number of intensifying threats expected.

Introduction

In the past, Arizona treefrog was grouped with *Hyla eximia*. It inhabits wetlands or streams in pine, oak, and mixed forests in Arizona, mostly at elevations above 5000 feet (Brennan and Holycross 2006). Populations in the Huachuca Mountains and Canelo Hills are disjunct from other populations in Arizona and Mexico, and may be a separate species based on genetic, call, and morphological differences (ENRD 2006, Gergus et al. 2004). Known as the Huachuca treefrog (ENRD 2006), these disjunct populations are candidates for federal listing, reviewed as of November 2009. Breeding habitats currently very limited. The Huachuca/Canelo distinct population segment is known from fewer than 20 localities, 11 of which have yielded observations of the frog in the last 10 years (USFWS 2008).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

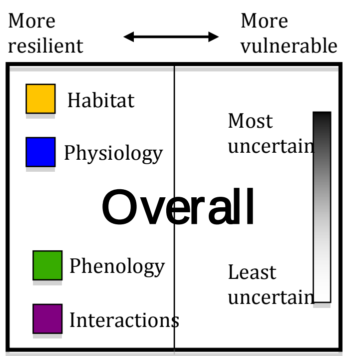
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates a neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**3.6**	14%
Physiology	**0.7**	17%
Phenology	**2.5**	25%
Interactions	**1.0**	40%
Overall	**8.0**	23%

Figure Key



Other threats and interactions with climate

The USFWS (2008) has identified a number of threats to this species. The most significant threats noted were high severity wildfires that result in habitat loss or direct mortality, drought, floods, introduced predator species, and habitat degradation caused by livestock grazing, off-highway vehicles, and environmental contamination. Limb deformities have been observed in this species (USFWS 2008). High severity wildfire, drought, and floods will all likely become more frequent or intense with climate change projected for the region, thus increasing these threats. Long term survival of this species is also threatened by its occurrence in small, disjunct populations. Climate change will likely further reduce connectivity among populations.

Research Needs

Monitoring of this species difficult, because breeding choruses of male Arizona treefrogs only last 2-3 days (Brennan and Holycross 2006). To restore or expand populations, there is a need to know if predator removal would be effective to increase suitable habitats. A related question that needs study is if the current use of temporary pools is a recent response to increased predation or are permanent waters unsuitable for other reasons? These questions have implications for effective management of this species.

Management Options

Forest management to reduce the risk of high intensity wildfires will help to protect habitats. In addition, management that considers isolating temporary pools from sources of predators and competitors will be beneficial. A multispecies approach to management will be required because of the conflicting needs of species of more permanent waters. It may be, however, that increasingly dry conditions may increase suitability of some currently permanent water sources that support large numbers of aquatic predators. Potential suitable habitats of the future should be evaluated based on surface water projections, proximity to current treefrog populations, aquatic predator population projections, and potential for dispersal. Reproductive failure from alteration of monsoon timing is additionally a concern, particularly if rainfall quantity is greatly reduced or arrival is late. Monitoring and/or intervention may be needed during years of weak or late monsoons especially if these periods are prolonged or occur over several years. Management actions related to stock tanks should consider impacts and benefits to this species including the potential for breeding and disease transmission.

Habitat: Arizona treefrog (*Hyla wrightorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Live in ponderosa pine, oak, and mixed forests. Seem to prefer mesic oak habitats and wet seeps during the day (USFWS 2008). Also heard calling from tree tops and found under rocks and logs. Ponderosa pine, oak, and mixed forests are subject to increasing fire occurrence with climate change, which is likely to reduce habitats.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Breed mostly in temporary water sources that lack predators (Brennan and Holycross 2006) including stock tanks and intermittent streams. Not known if these are required breeding habitats or if they have been extirpated from more permanent waters because of large numbers of native and non-native predators. Eggs have been found in permanent waters (NatureServe 2009). Egg masses attached to vegetation just below the surface (NatureServe 2009). Use waters with abundant vegetation along the shoreline (USFWS 2008). Permanent and temporary water likely to be reduced with higher temperatures.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Non-breeding individuals are found in trees or in moist locations such as leaf litter or burrowed in the soil. One individual found wintering in a debris pile (Brennan and Holycross 2006). Also been found in winter under boulders and in a deep rock fissure (USFWS 2008). Trees, leaf litter, and debris are prone to fires.	**1**

Habitat: Arizona treefrog (*Hyla wrightorum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Not known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Movements are generally limited in hylid frogs (NatureServe 2009). Low mobility.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats.	**0**

Physiology: Arizona treefrog (*Hyla wrightorum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Inactive in cold or dry weather (NatureServe 2009) May be prone to desiccation in non-breeding habitats. Although there may be some reduction for low temperature limits, this species is likely prone to desiccation away from water.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Arizona treefrog (*Hyla wrightorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Not known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Nocturnal behavior may help buffer from very hot conditions. No anticipated limitations for daily activity.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Arizona treefrog (*Hyla wrightorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Breed at the beginning of the summer monsoon season. Breeding is short, lasting 2-8 days in *H. eximia* (BISON-M). Adults leave breeding habitats shortly after breeding. Metamorphosis takes 6 to 11 weeks (Brennan and Holycross 2006). Breeding may not be solely triggered by rain as individuals in Scotia Canyon failed to breed in a year when temporary pools formed late and despite presence of permanent water sources (USFWS 2008).	**0**

Phenology: Arizona treefrog (*Hyla wrightorum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
		Breeding seems to be triggered by more than just rainfall. Maybe temperature or circadian rhythms, but unknown.	
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Needs ponds from January to June for breeding. Timing of availability of ponds is likely to change with changes in seasonal rainfall.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Failure to breed with late monsoons indicates some lack of timing flexibility, although breeding is not distant from resources.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year (NatureServe 2009).	**1**

Biotic Interactions: Arizona treefrog (*Hyla wrightorum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Adults probably eat various small invertebrates. Larvae probably eat algae, organic debris, and plant tissue (NatureServe 2009). No overall prediction for wide variety of food resources.	**0**

Biotic Interactions: Arizona treefrog (*Hyla wrightorum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Predators	Are important predator populations expected to change?	Predation thought to be reduced by use of terrestrial refuges during the day (USFWS 2008). Eaten by tiger salamanders. Ponds where they breed are generally too ephemeral for bullfrogs, thus reduced predation threat as compared to some other frog species (USFWS 2008). Mostly avoid aquatic predation in temporary ponds and terrestrial habits. Other sources of predation are not known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Limb deformities are often caused by trematode, *Ribeiroia ondatrae*, possibly interacting in synergy with toxins or introduced fish (Johnson and Sutherland 2003). Snails are an intermediate host and are often abundant in cattle ponds (Johnson and Lunde 2005 in USFWS 2008). Presence of intermediate hosts such as snails, other amphibians, and wading birds as well as factors related to transmission to growing tadpoles such as low growth rates or inactivity in response to predators (Johnson and Sutherland 2003). Chytridiomycosis not identified in wild populations, but individuals have been infected in laboratory setting (USFWS 2008). Exposure to chytridiomycosis as transferred from leopard frogs or bullfrogs is likely small in temporary ponds. Exposure to trematodes in stock tanks and although there is no known relationship of infection/limb deformity with projected climate change, use of stock tanks may increase as natural waters decline.	**1**
5. Competitors	Are populations of important competing species expected to change?	May compete with American bullfrog, but competition limited by use of terrestrial retreats.	**0**

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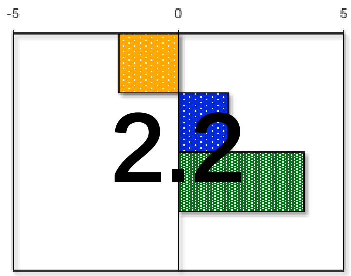


Desert Massasauga
(*Sistrurus catenatus edwardsi*)

SUMMARY

Desert massasauga has very limited populations and is vulnerable to extirpation from the U.S., thus any increase in threat is of concern. Habitat requirements for desert massasauga are not well understood making predictions about climate change effects uncertain although an increase in overall vulnerability is expected. This species may experience some expansion of habitats as climate change conditions encourage grasslands. At the same time, however, invasive African grasses are expected to increase with unknown consequences for suitability of this species' habitats. Additionally, this species is vulnerable to declines based on phenological characteristics, particularly timing of monsoonal rains.

Introduction

Desert massasauga is designated as a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and as sensitive by the USDA Forest Service. It is currently only known in Arizona from Sulphur Springs and San Bernardino Valleys (AGFD 2001). There is an historic record from Fort Huachuca, but this species may now be extirpated. The massasauga is widespread, but the desert subspecies is only found in a few disjunct populations in southeast Arizona, southeast Colorado, southern New Mexico and northern Mexico (Stebbins 1985).

Fort Huachuca climate and projections

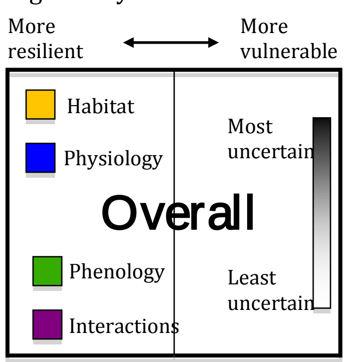
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-1.8**	29%
Physiology	**1.5**	33%
Phenology	**3.8**	50%
Interactions	**0.0**	60%
Overall	**2.2**	41%

Figure Key



Other threats and interactions with climate
Based on its association with seasonal wetlands and its very limited populations, this subspecies is considered vulnerable to extinction with a warming climate (Greene 1994). Limited distribution will interact with any declines associated with climate change or other threats to increase risk of extirpation. Habitat loss from agriculture cited as major factor in declines as well as habitat degradation due to overgrazing (AGFD 2001). The massasauga is also prone to mortality on highways. Grazing is likely to interact with climate change as behaviors and populations of grazing animals change along increasing variability in vegetative growth, but no information is available related to how grazing impacts these snakes.

Fires are expected to become more frequent as rainfall becomes more variable and temperatures rise. In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence as years of high rainfall are followed by dry/hot years creating conditions conducive both to ignition and fuel accumulation. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann's lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and is becoming increasingly problematic in the Sonoran Desert. The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor further conversion to grasslands. Fires and non-native grass invasions will encourage greater conversion to grasslands with unknown changes to habitat suitability for the desert massasauga.

Research Needs

Factors that led to population declines and the current disjunct distribution are mostly unknown. If grazing is a major threat, more information is needed on grazing variables that impact massasauga populations. Knowledge of the effects of non-native grasses on massasauga habitats will be critical as these grasses spread and invade native grasslands. Timing of monsoonal rains coincides with births, but the nature of this relationship is unknown making predictions difficult and beneficial management actions uncertain. Due to the current limited populations, an evaluation of suitable habitats and potential for dispersal could indicate the need for greater management intervention for this subspecies.

Management Implications

All populations are critical to survival of this subspecies in the U.S., although it is not generally of current management concern at Fort Huachuca as it appears to be extirpated. In addition, livestock grazing is limited at the Fort, thus any grazing impacts will be from native grazers. If massasaugas are found to be present in the area, management related to fire and invasive grasses will be critical to maintaining habitat for this species. Management actions that maintain water table levels will also be important to protecting seasonally wet grasslands.

Habitat: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupy desert grasslands in Arizona, but also known from oak woodlands in New Mexico. Grasslands may increase as woodlands retreat to higher elevations and fires increase.	**-1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Availability of burrows is not expected to change. More specific requirements are unknown.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Hibernates and uses burrows, vegetation, or leaf litter for refuges (Holycross 2003). Availability of burrows expected to stay the same.	**0**

Habitat: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Associated with grasslands that are seasonally wet (Greene 1994), which may improve conditions for foraging. More mesic conditions are partly dependent on variables such as topography and soils, but drying is expected with warmer temperatures and greater evaporation.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Radio-tracked individuals (*S. catenatus*) had large home ranges and movements in Colorado (NatureServe 2009). Known to move seasonally between habitats in some regions (NatureServe 2009) suggesting that mobility is not limited.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Unknown if move seasonally in Arizona.	**0**

Physiology: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. Occurs in a wide range of habitats and conditions throughout range. Often in vegetation associations with wetland habitats (NatureServe 2009). Fort Huachuca is part of hottest and driest part of the range and conditions may be near thresholds.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Primarily nocturnal in the summer, but also days when conditions are cooler. More surface activity is observed following monsoonal rains (Holycross 2003). Apparently is flexible in diurnal vs. nocturnal activity preference (NatureServe 2009). Changes to rainfall timing and greater evaporation are likely to reduce wet periods associated with activity.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No known strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	More surface activity is observed following monsoonal rains (Holycross 2003). Rainfall is potentially a cue. Temperature is likely a cue for hibernation.	**1**

Phenology: Desert Massasauga (*Sistrurus catenatus edwardsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Extended breeding season through much of the year although births may be limited to August and September (Holycross 2003). Not known if this timing relates to monsoonal rains, but seem possible considering the late dates of births. Monsoonal rains are subject to changes in timing.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Critical resources not known.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Females probably do not reproduce every year (Goldberg and Holycross 1999).	**1**

Biotic Interactions: Desert Massasauga (*Sistrurus catenatus edwardsi*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Venomous. Eats mostly lizards and small mammals, but also centipedes, spadefoots, and small snakes (Holycross 2003). No expected overall changes in wide variety of food items.	**0**
2. Predators	Are important predator populations expected to change?	No important predators known.	**0**

Biotic Interactions: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known, although may compete with other snake species for food. Similar snake species are likely to have the same vulnerabilities to climate change.	**0**

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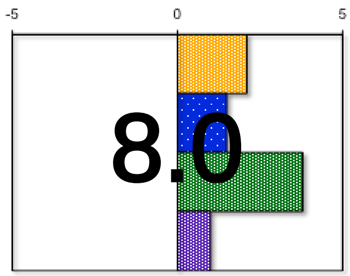


Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)

SUMMARY

Arizona ridge-nosed rattlesnake occupies high mountain refugia in southeastern Arizona and is expected to be vulnerable to declines associated with future climate change. Various aspects of this species' life history contributed to vulnerability, but the largest contribution was traits associated with timing or phenology. Management related to increasing forest resiliency to high severity fires and drought will be important.

Introduction

Arizona ridge-nosed rattlesnake is known to occur on Fort Huachuca. It is a species of greatest conservation need, Tier 1A Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and designated as a species at risk (SWESA 2006). It does not have federal protection, but another subspecies, the New Mexican ridge-nosed rattlesnake, *C. w. obscurus*, is federally threatened. Examination of systematics in these subspecies suggests that *C. w. willardi* may be the most distinct of the subspecies (Greene 1994).

Fort Huachuca climate and projections

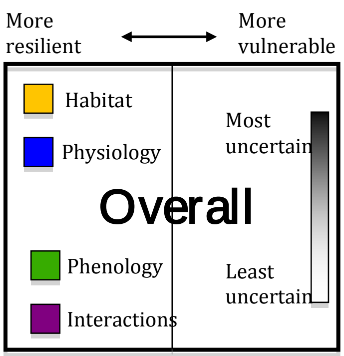
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.1**	43%
Physiology	**1.5**	17%
Phenology	**3.8**	50%
Interactions	**1.0**	60%
Overall	**8.0**	41%

Figure Key



Other threats and interactions with climate
Collecting of the New Mexican subspecies is considered a major threat and is likely to also threaten this subspecies. It has been suggested that this species is moderately vulnerable to climate change, but can survive in mountain refuges as it has during past climate change (Greene 1994). Isolation and shrinking habitats suggest future population declines, as does the outcome of this assessment. Small populations will be vulnerable to extirpation from various threats and Allee effects.

Research Needs
Many life history aspects and habitat requirements are not well known in this species. Variables related to canopy and fire history are important. Canopy or understory requirements and preferences are not known, but will be important to guiding forest thinning or prescribed fire applications. Population dynamics, measures of habitat suitability, or energetics as measured along an elevational gradient would help predict future impacts.

Management Implications

Fuels and fire management will be important to the extent that vegetation associations and preferred habitats are maintained, but it is difficult to predict how this species will respond to fire. High severity fires that remove the majority of canopy cover and leave little refugia, however, are likely detrimental. High densities of trees can increase fire severity and also susceptibility of trees to drought, thus thinning or prescribed fire may be useful for increasing resiliency to climate change effects for this species.

Habitat: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in Madrean oak and coniferous forests (Brennan and Holycross 2006). These habitats are expected to be reduced as they shift to higher elevations.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	None known.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Dens are used for hibernation. Variety of types and locations not expected to change overall.	**0**

Habitat: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	None known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Daily movements are limited (NatureServe 2009). Presence of roads was found to effectively isolate populations of timber rattlesnake (Clark et al. 2010), thus effective dispersal may be limited with current road networks.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Not migratory.	**0**

Physiology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Apparently intolerant of desert conditions. Current genetic isolation and speciation in sky islands may be due to desertification of lower elevations (Holycross and Douglas 2007). May not be tolerant of increasing temperatures.	**1**

Physiology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Hibernates during the extreme heat or cold (NatureServe 2009). No known response to fire or floods.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity appears to be somewhat flexible. Although mostly diurnal, also have some periods of nocturnal and crepuscular activity (Brennan and Holycross 2006). Greater activity, however, is also associated with rainfall (NatureServe 2009), which is expected to be reduced with warmer temperatures and greater evaporation.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Timing of hibernation or aestivation is directly related to temperature.	**1**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Venomous. Births occur late July through August (Holycross et al. 2001). This timing is coincident with monsoons, which may be important for obtaining greater amounts of prey. Expected changes to timing or variability of monsoons.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Centipedes and lizards may be important food resources for juveniles, but unknown how timing affects survival. Not known if rainfall triggers breeding.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year, but individuals may only breed biennially (Holycross et al. 2001)	**1**

Biotic Interactions: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats primarily lizards, centipedes, mice, but also birds and other invertebrates (Brennan and Holycross 1996). Rodents are generally taken by adults, and centipedes and lizards are taken more by juveniles (Greene 1994). Wide variety of prey species with no overall expected change to prey levels.	**0**
2. Predators	Are important predator populations expected to change?	No major predators known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	May den over winter with other individuals as in other rattlesnakes. More individuals could reduce metabolic needs and increase survival. Based on other sections of this assessment, populations may be reduced.	**1**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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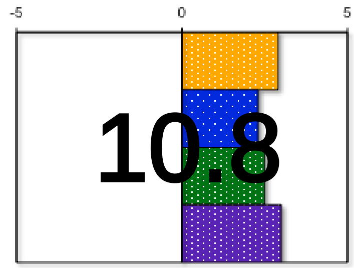


Northern Mexican Gartersnake
(*Thamnophis eques megalops*)

SUMMARY

Northern Mexican gartersnake is largely extirpated from its former range and now only occurs in a few isolated populations. We expect climate change to greatly increase its vulnerability to extinction through a variety of biological effects. In addition, a number of important current threats such as non-native species and loss of riparian habitats will likely be exacerbated. Management related to water table levels, protection of riparian areas, and control of invasive species will be critical.

Introduction

The northern Mexican gartersnake is a candidate species for federal listing as endangered or threatened (current as of November 2009) and a species at risk (SWESA 2006). It is a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). It occurs in Upper Scotia Canyon, Huachuca Mountains and historically occurred on the San Pedro River and Babocamari Cienega (USFWS 2006). Northern Mexican gartersnake has been extirpated from approximately 85% of historically occupied locations, which has been primarily attributed to the loss and degradation of riparian habitats (USFWS 2006). The northern Mexican gartersnake is one of ten subspecies and the only one in the U.S. (USFWS 2006).

Fort Huachuca climate and projections

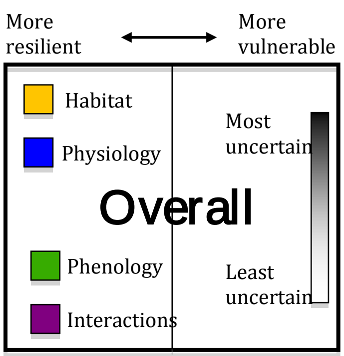
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.9**	29%
Physiology	**2.3**	17%
Phenology	**2.5**	25%
Interactions	**3.0**	40%
Overall	**10.8**	27%

Figure Key



Other threats and interactions with climate
Current threats include dams, diversions, groundwater pumping, introduction of non-native species (vertebrates, plants, and crayfish), woodcutting, mining, contaminants, urban and agricultural development, road construction, livestock grazing, wildfires, and undocumented immigration (USFWS 2006). Multiple threats occur at many locations and may work in synergy (USFWS 2006). Erosion and declining water tables, which are already implicated in declines, are likely to worsen with warmer temperatures, more severe flooding, and increased high severity wildfires. Grazing also can contribute to erosion and changes in hydrology as well as alter shoreline vegetation. Warmer temperatures and droughts may further concentrate grazing into mesic environments. There is also potential for increasing illegal immigration with climate change. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and government programs, both of which predict that drought impacts

will be less severe in the U.S. as compared to Mexico (Vásquez-León et al. 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected with potentially negative impacts for this species.

Research Needs
A number of areas are not well studied in this species. The effect of non-native animal species is well known, but the effect of non-native plants on habitats is not well studied despite current and future increases in the dominance of these species. Because of the large number of threats to this species and interacting effects, methods for identifying the most effective restoration measures is needed.

Management Implications
Management that restricts activities that can degrade riparian habitats will be important. Fuels management activities can reduce risk of high severity wildfires that are likely to threaten habitats and food sources. Management actions that mitigate climate change impacts for native amphibians and fish will be critical for the northern Mexican gartersnake in addition to those species. Control measures for non-native species in occupied habitats should improve survival. Although livestock grazing is limited on Fort Huachuca, native grazers may impact riparian areas during droughts. Stock tanks should be maintained and management should consider enhancements related to water retention and emergent vegetation. Protection of localities and targeting of management actions should anticipate future conditions and focus on those expected to be more resilient to drying.

Habitat: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies riparian habitats from 40 to 2,590 m (USFWS 2006). Associated with a variety of riparian types from mesquite grasslands to cottonwood gallery forests (USFWS 2006). It also uses stock tanks (USFWS 2006). Riparian forests are likely to decline with warmer temperatures.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	None known.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Associated with ungrazed habitats with high vegetation density and organic debris. Dense emergent vegetation along banks is likely important for foraging (USWFS 2006). Likely to be reduced as water tables drop.	**1**

Habitat: Northern Mexican Gartersnake (*Thamnophis eques megalops*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Small diameter trees may be important for thermoregulation and cover from predators (USFWS 2006). Vulnerable to water table declines.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Stock tanks may be important for dispersal (USFWS 2006) and likely restricted in dispersal because of habitat. May be able to disperse long distances during rainy periods. Likely restricted in ability to disperse although mobile.	**0**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. Activity restricted to relatively cool conditions for this region and may indicate low critical thresholds. May not be tolerant of higher temperatures.	**1**

Physiology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Severe flooding is considered a threat to this species (USFWS 2006). Flooding is expected to become more intense.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	The northern Mexican gartersnake is surface active at ambient temperatures ranging from 22-33 ºC (USFWS 2006). Time periods suitable for surface activity are likely to be reduced as temperatures warm.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Cues not known, but likely combination of external and internal signals.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Mating occurs in April and May with birth of live young in July and August (USFWS 2006). This period may coincide with monsoonal rains and favorable conditions for surface activity. Likely to be timing changes.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	No large separation between activities and events.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Approximately half of females reproduce in a single year (USFWS 2006).	**1**

Biotic Interactions: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats a variety of amphibians and fish, but thought to primarily prey on native species (USFWS 2006). Most native amphibians and fish are vulnerable to climate change and likely to decline.	**1**
2. Predators	Are important predator populations expected to change?	Large number of predators, but predation by introduced game fish and American bullfrogs are considered to be a major threat (USFWS 2006). These species are likely resilient to climate change, at least where water remains.	**1**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known major diseases (USFWS 2006).	**0**
5. Competitors	Are populations of important competing species expected to change?	Compete with American bullfrog for food (USFWS 2006). Bullfrogs are likely resilient to climate change.	**1**

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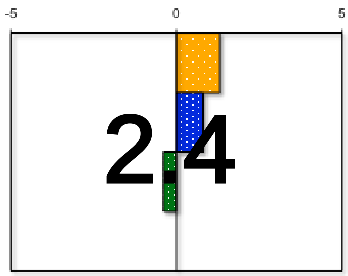


Bald Eagle
(*Haliaeetus leucocephalus*)

SUMMARY

Bald eagles winter in southeastern Arizona and are only likely to use Fort Huachuca occasionally as the Fort does not support adequate aquatic resources. Warmer temperatures are projected with greater warming in winter than in other seasons, thus changes will likely occur sooner on wintering grounds than in areas where eagles only occur in summer. Populations of bald eagles in Arizona were found to be only somewhat more vulnerable with climate change projections. Reservoir levels are likely to decline with increasing droughts and could impact wintering eagles in the Southwest.

Introduction

In lower 48, the species was listed as endangered in 1967 then for 43 states in 1978 and ultimately ending in delisting in the lower 48 in 1999. In 2004, Southwest populations were petitioned as a distinct population segment. Populations in the Sonoran desert were proposed as a distinct population and listed as endangered, but USFWS found listing was not warranted (February 2010), although the population segment briefly held status as threatened from 2008 while status was being reviewed. Individuals are only present in winter in southern Arizona. Wintering bald eagles have been seen at Willcox Playa, San Pedro, and Parker Canyon Lake, but any occurrence on the Fort is likely transitory (ENRD 2006).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

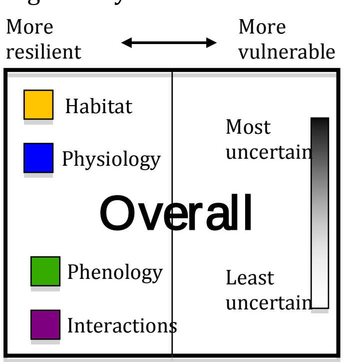
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	14%
Physiology	**0.8**	33%
Phenology	**-0.4**	25%
Interactions	**0.0**	20%
Overall	**2.4**	23%

Figure Key



Other threats and interactions with climate

DDT and shooting were important factors in past population declines, but now populations are increasing in many areas. Toxins from pesticides and heavy metals, however, continue to threaten this species through ingestion of contaminated prey (Buehler 2000). Habitat loss due to human development, particularly along shorelines, is still a major threat. On breeding grounds, climate change projections include earlier arrival of spring and increasing precipitation. Reproductive success can be reduced by wet and cold weather. The outcome will depend on the interaction of phenological changes in bald eagle arrival and phenology of spring weather conditions. In addition, earlier arrival on the breeding grounds is associated with better success because early individuals have access to the best sites. It is unknown how these timing changes will interact to affect breeding and consequently wintering populations in Arizona. Although overall we did not anticipate that food resources would be reduced, there may be some reductions in Arizona where eagles are primarily associated with reservoirs that will shrink with more frequent droughts and greater evaporation.

Research Needs

Many aspects of bald eagle ecology are well studied, but information is more limited on wintering ecology. Better information on how aspects of winter habitat may affect population dynamics would be useful. No information on how droughts may affect bald eagles, but important interaction for populations that winter in the Southwest. Stopover requirements are also not well known and could be impacted by climate change differently than breeding or wintering habitats.

Management Implications

Fort Huachuca, although adjacent to a wintering area, probably provides only limited foraging habitat, thus management activities are not expected to have much affect on local eagle populations. Availability of roost sites may encourage use of particular foraging areas. Forest management such as thinning and prescribed fire can enhance or be compatible with maintaining bald eagle roosting sites (DellaSala et al. 1998).

Habitat: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Breeds near aquatic habitats adjacent to forests or cliffs mostly in northern North America (Buehler 2000). Reductions in aquatic and shoreline habitats may be expected with sea level rise, but individuals in Arizona more likely breed in inland in Canada and the Rocky Mountains where precipitation is expected to increase (www.climatewizard.com, A2 emissions, ensemble GCM). No change expected for interior aquatic breeding areas.	**0**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Winters at rivers, reservoirs, and other aquatic habitats (Buehler 2000). Inland lakes and playas nearby to Fort Huachuca probably reduced by reduced precipitation and evaporation during warmer temperatures.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Requires large trees for nesting. Breeding grounds for AZ individuals are not known, but likely that large trees will remain available near interior aquatic habitats in northern locations.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Roost trees are generally large and protected from winds. These trees may be susceptible to mortality from drought or shoreline fluctuations.	**1**

Habitat: Bald Eagle (*Haliaeetus leucocephalus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Factors affecting reproductive success not well known, but most discussion is related to association with DDT levels. In an Alaska study, vegetative characteristics of the habitat were only weakly related to reproductive success (Hansen 1987).	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Arizona individuals may move through intermountain region to breeding areas in the north. Use transitional habitats, although extent of reliance on stopover habitats is not well documented.	**1**

Physiology: Bald Eagle (*Haliaeetus leucocephalus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	No known limitations, although cold limiting conditions may improve. Cold not likely limiting in Arizona.	**0**

Physiology: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Little recorded mortality related to exposure beyond indirect effects through food supply (Buehler 2000). Reproduction, however, may be reduced during cold wet springs (Buehler 2000). Reproduction reduced during cold and wet springs. Warmer temperatures may reduce losses, but heavy precipitation events may alone be detrimental and become more common. Overall, no anticipated change.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	None known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate.	**0**

Phenology: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Leave breeding grounds based on food abundance (Buehler 2000).	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Migration routes and timing follow salmon runs in some regions. Prey availability is important. In some populations peak availability of spawning fish such as salmon may change, but interior populations, where salmon are extirpated, are probably most closely linked to fish populations that are relatively constant.	**-1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Movement from breeding grounds may be signaled by declines in food abundance. Already arrive in some areas to breed while waters are still frozen, but earlier arrival is advantageous to securing breeding sites (Buehler 2000). Cues are not distant from migration or breeding.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event per year.	**1**

Biotic Interactions: Bald Eagle (*Haliaeetus leucocephalus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Wide variety of prey items including birds and mammals, but prefers fish. Often scavenges or steals prey from other predators (Buehler 2000). Probably eats both warm- and cold-water fishes in Arizona. No anticipated changes in overall prey availability in existing lakes. Fish are stocked at Fort Huachuca all species are non-native.	**0**
2. Predators	Are important predator populations expected to change?	Predation is not likely a major factor in mortality.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases that affect populations. Most deaths are directly or indirectly related to humans (Buehler 2000).	**0**
5. Competitors	Are populations of important competing species expected to change?	Competes with other scavengers and raptors, but little information on these interactions. Steals prey from other carnivores. No overall change in competitive outcomes anticipated.	**0**

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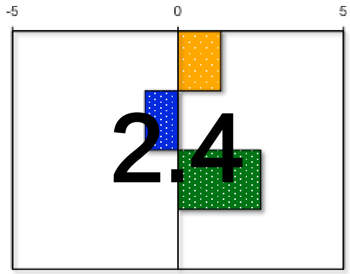


Northern Goshawk
(*Accipiter gentilis atricipillus*)

SUMMARY

Northern goshawks were assessed to be somewhat vulnerable to declines associated with climate change. Mature forests with high canopy closure, which are preferred breeding habitats, will be vulnerable to drought mortality and fires. Goshawks are fairly flexible in movements, winter habitats, and prey selection, which will help to balance negative impacts that are anticipated. Management related to fire severity will be important and future changes in breeding timing in this species should be anticipated.

Introduction

The northern goshawk ranges widely in forests across most of North America. Goshawks in southern Arizona and Mexico are also sometimes identified as *A. g. apache*, but there is disagreement over the classification of the subspecies (Squires and Reynolds 1997). The Northern goshawk is a federal species of concern and a species of greatest conservation need, Tier 1B, in the Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and designated as a species at risk (SWESA 2006). They are also identified as sensitive by the USDA Forest Service.

Fort Huachuca climate and projections

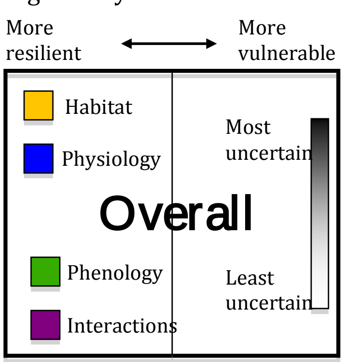
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	14%
Physiology	**-1.0**	33%
Phenology	**2.5**	25%
Interactions	**0.0**	40%
Overall	**2.4**	27%

Figure Key



Other threats and interactions with climate
Currently, there is no evidence that goshawk populations are declining in North America (Kennedy 2003). The largest current threat is generally considered to be logging of preferred habitats (Kennedy 2003).

Research Needs
Little is known about what level of fire occurrence is important for longterm sustainability of habitats at a landscape scale, which will be important in incurring resilience of forests, as well as goshawk habitat, to climate change. Information is also limited on physiological thresholds or timing of resources that affect breeding success.

Management Implications
Logging is often considered the greatest threat to this species and does not occur on Fort Huachuca. Fuel treatments may have negative impacts, but increasing fuels will be prone to high severity fires, which will reduce habitats for long periods. These

and other actions related to fire management will be important as fire incidence is expected to increase with projected climate change. Additionally, dense stands will be more vulnerable to tree mortality during droughts than more open stands. Effective management planning for this species therefore needs to balance a number of impacts and benefits at a landscape scale. Management for this species often includes restriction of activities during the nesting season. Dates of activity restriction may need to be reevaluated as breeding phenology in this species may change.

Habitat: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Nests in various mature pine and mixed pine-oak habitats (Squires and Reynolds 1997). Mature forests are vulnerable to upward elevation shifts and increasing high severity fires.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above, but may use additional non-forested habitats. Prey abundance may be more important than habitat for wintering goshawks (Squires and Reynolds 1997). No change in overall area expected for the broader range of winter habitats.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Requires large trees for nesting and mostly chose ponderosa pines in the Southwest (Squires and Reynolds 1997). No expected changes for large ponderosa pines within suitable breeding habitat.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	In Arizona, choose forests with 60% and 69% canopy closure (Squires and Reynolds 1997). Association with closed canopy forests may reduce predation in this species (Squires and Reynolds 1997). Tree mortality associated with droughts and insect infestations may decrease canopy closure.	**1**

Habitat: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Moderately dense forests may be best foraging habitats (Squires and Reynolds 1997) and may be prone to loss from increasing fires as well as insect infestations.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	High mobility	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats required, although seasonal movements are not well known.	**0**

Physiology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Little information, but thresholds not expected to be exceeded.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Cold and wet conditions result in nest failures although this is mostly from studies in Europe. Severe rainstorms may increase, but may not co-occur with nesting, which is early in the year. No anticipated increases in disturbance mortality	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity is generally linked with prey activity periods (Squires and Reynolds 1997). Although these periods may change, goshawks appear flexible in activity timing. No anticipated changes overall.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	At northern latitudes, this species sometimes has irruptive movements related to resource availability. We assume a similar flexibility is present in southern populations and may allow it to cope with fluctuating resources.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Not known, but likely a combination of internal and external signals.	**0**

Phenology: Northern Goshawk (*Accipiter gentilis atricipillus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Eggs laid late April to early May with some weather-associated variability (Squires and Reynolds 1997). May be timed to coincide feeding of young with availability of young birds and mammals. Phenology of these events is likely to change.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding does not occur far in advance or at distant location from wintering areas.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One brood per season (Squires and Reynolds 1997).	**1**

Biotic Interactions: Northern Goshawk (*Accipiter gentilis atricipillus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Opportunistic carnivore. Main food items include birds, rabbits, and squirrels. Starvation is the most common cause of mortality (Squires and Reynolds 1997). Variety of prey items, not all expected to decline or increase simultaneously.	**0**

Biotic Interactions: Northern Goshawk (*Accipiter gentilis atricipillus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Predators	Are important predator populations expected to change?	Few predators for adults, but some predation from larger raptors (Squires and Reynolds 1997). No expected change.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No major diseases known that affect populations.	**0**
5. Competitors	Are populations of important competing species expected to change?	May compete with other predators for food. Will attack and kill other raptors, including red-tailed hawks. No important competitive interaction known.	**0**

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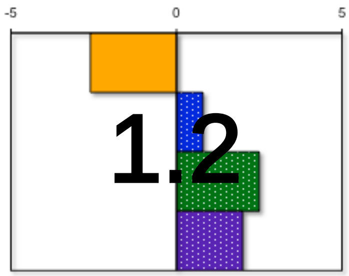


Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

SUMMARY

The aplomado falcon, although not currently present on Fort Huachuca, has potential for future occurrence. This falcon could benefit if grasslands increase with a warming climate, but important habitat associates, such as woodlands and riparian forests, will be threatened by increased occurrence of high severity wildfires and declining water tables. Aspects of the future threats to this species, such as dependence on riparian areas or effects of drought, are poorly known and made assessing vulnerability uncertain.

Introduction

The northern aplomado falcon is a federally endangered species, and although not known to occur on Fort Huachuca, potential habitat is present (ENRD 2006). Individuals were reintroduced in Texas in the 1990s and in New Mexico beginning in 2006. Southwestern populations are considered experimental and non-essential although they may not truly be isolated from wild populations. Aplomado falcon is subject to status review as of March 2010 (Federal Register: 75 FR 15454-15456).

The Peregrine Fund reports more than 40 wild pairs nested in Texas in 2008. Individuals in the U.S. may be part of captive breeding programs but there is also evidence of migration from Mexican populations (Keddy-Hector 2000). Any individuals located at Fort Huachuca could be from those released in New Mexico, but could also migrate from wild populations in Mexico. Population status and trends are mostly unknown because of limited historic information and lack of contemporary population monitoring.

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)

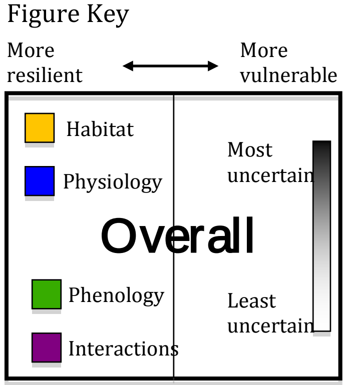
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith et al. 1984)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-2.6**	0%
Physiology	**0.8**	33%
Phenology	**2.5**	25%
Interactions	**2.0**	40%
Overall	**1.2**	23%

Figure Key



Other threats and interactions with climate
DDT and secondary lead poisoning are thought to be important sources of mortality (Keddy-Hector 1990). Populations in the U.S. are still contaminated with heavy loads of organochlorines, heavy metals, and PCBs, which limits recovery efforts (Keddy-Hector 2000). Extirpation of prairie dogs from much of their range may also be a factor in declines (Keddy-Hector 2000). Low reproductive rates that limit expansion of populations from Mexico into the U.S. are thought to be linked to drought. To the extent that droughts are limiting to expansion of aplomado falcon,

populations in the Fort Huachuca area may decline further in the future as droughts become more severe. Encroachment of grasslands by shrubs, often associated with overgrazing, has been cited as a cause of habitat losses along with loss due to agriculture and water diversions (Keddy-Hector 2000). Although for the purposes of this document we assumed a warmer climate would favor grasses over shrubs, season of precipitation, current vegetation, fires, and various other factors will interplay to affect the future vegetation trajectory. There is potential, however, that suitable grassland habitats will increase in the region.

Research Needs
Information is needed on pesticide levels and interactions with falcons for various prey items (Keddy-Hector 2000). This threat may interact with climate as relative prey availability is likely to fluctuate and, thus, exposure to these compounds may change. Invasive grasses are increasing in Arizona and may be encouraged by climate change, but information on their effect on aplomado falcon habitat is needed. In addition, drought and degradation of riparian areas are generally cited as responsible for declines, but the mechanism behind this response is unknown and is needed to effectively manage this species.

Management Implications
Aplomado falcons are not currently protected as the origin of Arizona individuals is usually considered part of the experimental population. Status could change in the future. Fires that accompany higher temperatures and more variable rainfall could help increase grasslands, thus increasing habitat for the falcon. An increasing proportion of these grasslands may be made up of non-native species, but this has an unknown effect on falcon populations. Use of prescribed fire is likely compatible with habitat preservation especially if intensities are low enough to not burn nesting substrates. A number of identified vulnerabilities were related to timing and quantity of prey. Management is unlikely to affect timing of peak prey availability, but protection of a variety of prey sources may help increase resilience. Larger areas of suitable habitat potentially could help this species survive drought conditions or variable prey populations. If falcons are present on Fort Huachuca then management measures such as timing of military activities and protection of stick nests may be necessary. These measures, if implemented, also need to anticipate phenological change in response to a warming climate.

Habitat: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The aplomado falcon inhabits various desert grasslands and coastal prairies in the US-Mexico border region, the Gulf Coast of Mexico, and parts of Central America. Suitable grassland habitats often are associated with scattered trees and shrubs or edges of riparian woodlands (Keddy-Hector 2000). In the U.S., associated with scattered mesquite and yuccas (Keddy-Hector 1990). Grassland habitats may benefit from more frequent fires and warmer temperatures.	**-1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within the associated vegetation type?	Nests are in stick platforms built in trees or other structures by other raptors or corvids. They are also known to use nests in cliffs or on power lines (Keddy-Hector 2000). Yuccas are often used for nesting in the U.S. (Peregrine Fund website). High severity fires may threaten plants with suitable structures for nest platforms such as yuccas or trees.	**1**
4. Habitat components: *non-breeding*	Are specific habitat components required for survival during non-breeding periods expected to change within the associated vegetation type?	None.	**0**

Habitat: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality and reproduction	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Generally associated with more open habitats, which are probably improves success for hunting of ground feeding birds. Increasing droughts and fires may open habitats.	**-1**
6. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats required.	**0**

Physiology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	U.S. populations are at the northern limit of current range and former range is not well known (Keddy-Hector 2000). Occupies various habitats including deserts. No physiological limitations known.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Adults are most active at dawn and dusk, and may hunt well before or after dark (Keddy-Hector 2000). Hunting activity does not seem to be strictly limited to this period. Spends much of the day perched.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No. They cache prey items and retrieve them to feed to nestlings (Keddy-Hector 2000). Food caching behavior is likely limited to feeding of young.	**1**
6. Metabolic rates	What is this species metabolic rate?	Endothermic, moderate.	**0**

Phenology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Not known, but likely combination of internal and external cues.	**0**

Phenology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	In the U.S., most aplomado falcons lay eggs in April-May, but in eastern Mexico lay eggs January-June, during the dry season (Keddy-Hector 1990). Nesting may be timed to occur just before nesting of resident birds and arrival of spring migrants (Keddy-Hector 2000). Timing of breeding to fledgling of other bird species and spring emergence of insects is likely important. Both these events may vary with changes in temperature.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Cues to initiate breeding are not known but species is resident so not distant from breeding grounds.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Second broods are possible, but not documented (Keddy-Hector 2000).	**1**

Biotic Interactions: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Eats mostly small birds and insects (Keddy-Hector 2000). Dominant bird prey are those that feed on the ground or in short direct flights. These species include grackles, doves, nighthawks, and meadowlarks (Keddy-Hector 1990). They also steal kills from other avian predators (Keddy-Hector 2000). Diet is various, but birds likely make up most of the biomass consumed. Loss of riparian woodlands is thought to have contributed to declines because of reductions in available avian prey (Keddy-Hector 1990). Further loss of	**1**

Biotic Interactions: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		riparian areas and dependent bird populations with climate change may reduce avian prey.	
2. Predators	Are important predator populations expected to change?	Predators of nests are likely various and larger raptors may prey on adults (Keddy-Hector 2000). Predation was a major cause of death of released birds in Texas (Keddy-Hector 2000), but susceptibility of captive-raised falcons may differ from wild-born. No important predators known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Generally dependent on other birds to build large platform nests (Keddy-Hector 2000). These include nests of various species including ravens and red-tailed hawks. Both these species are widespread and tolerant of human activities, thus perhaps tolerant of changing climate.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Prone to trichomoniasis transmitted by dove populations. There is some potential for greater transmission as doves concentrate at fewer water sources and with increasing urban development.	**1**
5. Competitors	Are populations of important competing species expected to change?	May compete for stick nests, but no information on this potential issue. Also steals prey from other raptors so apparently a strong competitor.	**0**

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Seager, R., T. Mingfang, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. P. Huang, N. Harnik, A. Leetmaa, N. C. Lau, C. Li, J. Velez, and N. Naik. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316:1181–1184.

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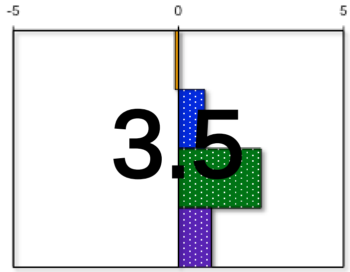


American Peregrine Falcon (*Falco peregrinus anatum*)

SUMMARY

Peregrine falcons are flexible in habitat use, which will help them cope with climate change effects to some extent. Phenology, as related to prey levels, is an area of potential vulnerability depending on if different aspects shift in synchrony. Although Arizona habitats are expected to remain suitable, they will be exposed to other climate change effects at wintering and stopover sites. Restriction of activities at nesting sites needs to adjust for future timing changes.

Introduction

Peregrine falcons have nested on Fort Huachuca in recent years (at least one pair) and there are other breeding territories in nearby surroundings (ENRD 2006). They were federally listed in 1970 and delisted in 1999. Peregrine falcons are a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and is designated as a species at risk (SWESA 2006).

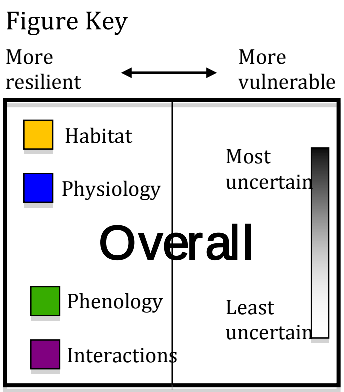
Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin et al. 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin et al. 2007)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-0.1**	0%
Physiology	**0.8**	33%
Phenology	**2.5**	25%
Interactions	**1.0**	40%
Overall	**3.5**	23%



Other threats and interactions with climate
Population declines in the past are thought to be primarily due to DDT and populations are currently recovering. Because this species is migratory, climate or land use changes in Mexico and Central America will affect populations at Fort Huachuca.

Research Needs
Wintering habitat requirements for this species are not well known. Migration routes and destinations are also not well known for populations in the Southwest. In addition, physiological thresholds as they relate to increasing temperatures in hot portions of their range are needed to predict climate change response.

Management Implications

Territory size and spacing is related to nest site and prey availability (White et al. 2002), which is probably relatively low in this region. Thus it is unlikely that local management actions will affect more than a few individuals. Peregrine falcons drink frequently (White et al. 2002) and water needs will likely increase in the future, thus management related to water sources, including artificial waters, will be important. Restriction of activities at suitable nesting sites is important and managers should plan for shifts in breeding timing.

Habitat: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies a wide variety of habitats including forests, grasslands, and scrublands (White et al. 2002). Most of Fort Huachuca is suitable vegetation and should continue to remain suitable despite proportional changes in specific vegetation types.	**0**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Occupies even wider range of habitats in winter. No expected changes.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Vertical substrate with ledges for nesting. Mostly cliffs, but will also use buildings in urban areas. No projected changes to cliffs.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Uses perches to scan for prey. Wide variety of perch locations with no expected change in availability.	**0**

Habitat: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Reproductive success has been related to female age, but not habitat variables (White et al. 2002).	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Migratory. Birds that breed in more southerly locations may actually travel less south into Mexico than those that breed in the far north, which may travel to Central America to winter (White et al. 2002).	**1**

Physiology: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. One of the most widely distributed vertebrate species, peregrine falcons are tolerant of a wide range of conditions (White et al. 2002). Convective cooling through the bare tarsus is considered important and this surface area varies with region (White et al. 2002). Not expected to be limited.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Thought to be less prone to mortality from adverse weather during migration than many other bird species (White et al 2002). Nestlings vulnerable to late wet springs (White et al. 2002). Spring expected to occur earlier rather than later although this may not be a major factor in warmer climates.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Most cooling is through behaviors such as orientation, erection of feathers, or panting. No known limitations to daily active period.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known. Only rare records of cooperative breeding (White et al. 2002).	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic, although higher than congeneric species (White et al. 2002).	**0**

Phenology: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Timing of migration and breeding seems to be in response to a wide variety of signals including climate, photoperiod, and prey levels (White et al. 2002). Not directly in response to temperature alone.	**0**

Phenology: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Based on areas with similar climates, egg laying occurs from March to April (White et al. 2002). Likely that breeding is timed to prey levels that fluctuate with breeding of other species, which, in turn, is subject to climate-related changes.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	In some areas, migratory behaviors seem to be directly in response to prey levels (White et al. 2002). This seems to be limited to leaving breeding grounds and breeding timing is not likely to be very flexible to resource timing.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One brood per year.	**1**

Biotic Interactions: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Most important prey items are birds although a wide variety of species from various taxonomic groups are also eaten (White et al. 2002). Doves are likely important prey in this region and may benefit from developed areas of the Fort. No expected overall changes in prey available.	**0**

Biotic Interactions: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Predators	Are important predator populations expected to change?	Great horned owls are an important predator on young, but predation for adults is probably not frequent. No expected changes in predation levels.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Some secondary infection through prey of *Trichomonas* (White et al. 2002). May increase with increased transmission in doves from crowding at artificial feeders or shrinking water sources.	**1**
5. Competitors	Are populations of important competing species expected to change?	No major competitors known.	**0**

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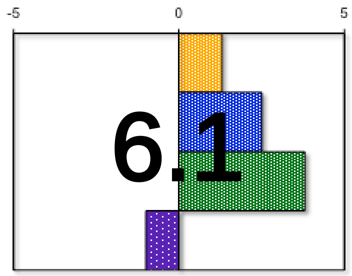


Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)

SUMMARY

Western yellow-billed cuckoos have small fragmented populations and are likely to be subject to greater stress with projected climate change. Riparian habitats, which yellow-billed cuckoos rely on, have already greatly declined and are expected to be exposed to further degradation and loss. Physiological aspects as well as timing and reproduction were both identified as vulnerable areas for this species. Of potential benefit; periodical cicadas are an important food resource in some years and will likely be tolerant of projected changes. Facultative brood parasitism has the potential to increase populations during periods of high resource levels, but very little incidence of this behavior has been recorded. Overall, many life history aspects are poorly studied in this species, thus vulnerability assessment is relatively uncertain.

Introduction

Historically, yellow-billed cuckoos bred throughout the U.S., but have now declined and, in the West, only occur in fragmented populations. The western population of the yellow-billed cuckoo is considered distinct from eastern populations and has been a candidate for federal listing by the U.S. Fish and Wildlife Service (USFWS) since 2001. Although there has been some disagreement over whether the there are valid eastern and western sub-species, USFWS (2001), citing Franzreb and Laymon (1993), recognized the western subspecies (*C.a. occidentalis*). Sufficient evidence was obtained for listing, but it was precluded by other higher priority listing actions (66 Federal Register 38611). It is also identified as a species of greatest conservation need, Tier 1A, in the Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and a species at risk (SWESA 2006). Yellow-billed cuckoos occur at Fort Huachuca, although much larger numbers are present nearby on the San Pedro River. Primary riparian areas on the Fort are in Garden, Huachuca, and McClure Canyons (ENRD 2006).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)

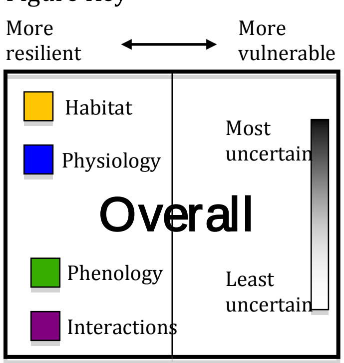
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin et al. 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin et al. 2007)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	43%
Physiology	**2.5**	50%
Phenology	**3.8**	50%
Interactions	**-1.0**	40%
Overall	**6.1**	45%

Figure Key



Other threats and interactions with climate
In arid regions, yellow-billed cuckoos occur in riparian habitats. Continued loss and degradation of riparian habitats is a major concern, including invasion by salt cedar (*Tamarix* spp.). Without considering climate, water tables are likely to be lower on the Upper San Pedro even with conservation measures (Steinitz et al. 2005). Comparisons of salt cedar dominated vs. cottonwood-willow dominated habitats on the San Pedro indicate that surface flow permanence was the most important determinant of plant species dominance (Lite and Stromberg 2005), thus, with warmer temperatures and continued water table withdrawals (Stromberg et al. 1996), we may expect greater dominance of salt cedar on the San Pedro River. Fires are also a concern in riparian habitats as cottonwoods are prone to fire mortality, but shrubby regrowth following fire may attract cuckoos. Western populations are very small and fragmented so are more vulnerable to stochastic events including those related to extreme climate events.

Water diversion will likely increase with hotter and drier conditions placing more stress on riparian systems. Pesticides have been implicated in mortality and population declines (Hughes 1999). The migratory habits of this species make coordinated conservation efforts that span the entire species' range difficult. Also many deaths due to collisions have been reported, which may be an issue if wind farm developments within the species' range increase to create more sustainable forms of energy.

Historically, yellow-billed cuckoos seem to have nested in a wider range of habitats, including non-riparian habitats, than today. One possible explanation that has been presented is that exposure to pesticides have increased moisture loss in eggs causing reduced hatchability and making drier habitats unsuitable (Laymon and Halterman 1987). Pesticide restrictions in the U.S. are limited in their protection for neotropical migrants. Hotter and drier conditions will exacerbate egg drying and restricting cuckoos further to riparian areas.

Research Needs
The effect of pesticides and interaction with increasing temperatures is potentially of importance with warming climate, but has not been studied. More information is also needed on the role of brood parasitism (both intra and inter specific) in population dynamics.

Management Options
Fort Huachuca has a wetlands management program specifically to protect wetland resources including riparian habitats (ENRD 2006). Fort Huachuca has implemented water conservation to reduce ground water pumping, which may help protect riparian habitats for yellow-billed cuckoo on Fort Huachuca, although the relation of ground water to San Pedro surface flows is unresolved (ENRD 2006). At the Fort, ground water levels are monitored (ENRD 2006). Some upland land

manipulations can also increase surface flows, but these effects are usually temporary. As cuckoos are restricted to riparian areas, military exercises probably have little direct impact on this species. Negative impacts indirect effects of military activities such as increases in ignition sources, invasive species spread, and water withdrawals should be limited when possible. Fire management and invasive species control will be important.

Habitat: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Yellow-billed Cuckoos prefer open woodlands with low, dense shrubby vegetation at elevations up to 1500m (Hughes 1999). Proximity to water appears important, either directly or indirectly, in all preferred habitats. The majority of nests were found by Arizona Breeding Bird Atlas (Corman and Wise-Gervais 2005) along perennial drainages. In Arizona they prefer desert riparian forests of the Sonoran Zone, comprised of willow, Fremont cottonwood, and dense mesquite (Hughes 1999). For 2-3 weeks before breeding, they may occupy upland vegetation including pinyon, oak, juniper, and manzanita (Hughes 1999). Associated with riparian habitats with willow and cottonwood, which are expected to decrease with reduced stream flows, lower water tables, higher temperatures, and changing flood regimes. Higher temperatures are also associated with an increase in fire, which generally kills cottonwoods, although there would be some benefit in increasing of shrubby habitats if fire area is not too extensive.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	It is thought that this subspecies winters primarily in northwest South America (Hughes 1999). Overall, wintering birds occupy a wide variety of forests, woodlands, and scrubby areas, preferring "woody vegetation bordering fresh water (Rappole et al. 1983 and Stotz et al. 1996 in Hughes 1999). Winter habitat is reported as mangroves and riparian habitats in Surinam and Guyana (Tostain et al. 1992, Haverschmidt and Mees 1994 in Hughes 1999). In Venezuela, they have been observed in open woodlands, second growth, and thickets (Meyer de Schauensee and Phelps 1978 in Hughes 1999). Not well known, but seem to be associated with a number of scrub and woodland habitats in South America. In some regions, savannahs are expected to replace tropical forest, which may increase wintering habitats, but also associated with mangroves, which are vulnerable to sea level rise. Overall, no predicted change in winter habitat area.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Cottonwoods are used extensively for foraging and nests are often placed in willows. In western U.S., nests in Fremont cottonwood, mesquite, hackberry, soapberry, alder, and cultivated fruit trees, but trees need to be large enough with horizontal branches for support (Laymon 1980 in Hughes 1999). Lowering of water tables and increases in fires are likely to reduce trees large enough to support nests.	**1**

Habitat: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	No information.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Cuckoos typically select nest sites with very dense cover, particularly overhead. Although there may be a relationship, it is not known if this is associated with reproductive success, but not expected to change within suitable habitat.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Both sexes are highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Long distance migrant through Mexico and Central America. In addition, for 2-3 weeks before breeding, they may occupy upland vegetation including pinyon, oak, juniper, and manzanita.	**1**

Physiology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Southern Arizona is in the south-eastern portion of the sub-species range in the U.S. Western populations are very local in scattered riparian areas from Montana to Mexico. The species formerly bred throughout most of North American from southern Canada to northern Mexico (USFWS 2001). In the western U.S., this subspecies breeds in riparian areas in western U.S., which provide shade and a relatively cooler microclimate. Incubating adults and nestlings have been observed panting on hot days (Hughes 1999). Some have proposed that pesticide use has made eggs prone to detrimental effects of drying (Laymon and Halterman 1987), but no experimental data is available. Very little known. Restricted to riparian areas in hot regions, which are cooler and more humid than surroundings. Taken together, these facts may indicate a relative intolerance to hot dry conditions, which are expected to increase on the breeding grounds.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Veit and Petersen (1993, in Hughes 1999) report that in 1954, many weakened and starving yellow-billed cuckoos were observed in northeastern states following the passage of 3 hurricanes. Hurricane intensity is expected to increase under global climate change, but hurricane frequency predictions, which are more likely to increase mortality, are inconsistent (Emanuel 2005). Populations migrating to Arizona likely remain inland where they are more protected from hurricanes than those crossing the Gulf of Mexico. Several intense rainfall events have been reported for Venezuela, which may also result in mortality. These occurred in September (Columbia) and February (Venezuela), and thus may coincide with yellow-billed cuckoo presence. May be increased mortality with increased exposure to hurricanes, but exposure is probably not high for western populations. More intense rain storms are also predicted for South America, which may increase mortality for some species, although effect on cuckoos is largely unknown	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	The Western subspecies breeds in riparian areas, which provide shade, thus can escape highest temperatures. No other information on activity in relation to climate variables.	**0**

Physiology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Brood parasitism is facultative in this species. Rates of brood parasitism and consequences for reproductive success are not known. There is some suggestion that periods of high resource availability during breeding such as emergence of cicadas may allow for larger clutches and increased intraspecific brood parasitism (Fleischer et al.1985). Resource availability might then also be expected to be related to interspecific brood parasitism as well. Has both inter- and intra-specific brood parasitism. May be able to lay larger clutches and lay extra eggs in nests of other individuals. This behavior has the potential to increase breeding success during years of high resource levels. Increased breeding opportunities through brood parasitism may be expected to increase populations during high resource years, but no effect of this behavior on populations has yet been documented. Rates of brood parasitism are also not well known, but currently there are few records of occurrence, which may indicate this behavior is too rare to affect populations.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	No information. Assume combination of external and internal signals for migration and breeding.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Breeding initiation often coincides with rainfall and is thought to be related to food availability (Nolan and Thompson 1975 in Hughes 1995). In the West, yellow-billed cuckoos arrive relatively late in spring (mid May) compared to the eastern subspecies or many other migratory birds (Hughes 1999). Viet and Petersen (1993) report that birds may not breed in years when food supply is low and these periods may increase as droughts become more frequent. Breeding initiation may be correlated with abundance of local food	**1**

Phenology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		or periods of greatest precipitation. Changes in precipitation and temperature may alter timing of insect emergence.	
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration and breeding separated by large temporal and spatial gap.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Populations in the western US are believed to raise only one brood per season and breeding season is shorter than in the eastern U.S. (Hughes 1999). Recent information found evidence that yellow-billed cuckoos may breed a second time in western Mexico after migrating from the north (Rohwer et al. 2009), which may allow this species take advantage of seasonal resources in multiple locations. Because very little is known about this second breeding, we assume only one brood per year.	**1**

Biotic Interactions: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Cuckoos feed primarily on large insects such as caterpillars, grasshoppers, crickets, katydids, cicadas, and sometimes on small lizards, frogs, eggs, and nestlings (Hughes 1999). Cuckoos on wintering grounds also feed on fruits and seeds in addition to insects (Hughes 1999). Populations fluctuate greatly with food availability and can increase dramatically in years of highest insect abundance such as tent caterpillar infestations and cicada cycles (Hughes 1999). Cicadas are behaviorally and physiologically tolerant of high temperatures (Heath and Wilkin 1970). In addition, they have high reproduction in salt cedar (Glinski and Ohmart 1984) and, thus, may be expected to be resilient to projected climate changes in the breeding range. Cuckoos feed primarily on large insects such as caterpillars, grasshoppers, crickets, katydids, cicadas. They also feed on small lizards, frogs, eggs, fruits, seeds, and nestlings. Cuckoo populations fluctuate greatly with food availability and increase dramatically in	**-1**

Biotic Interactions: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		years of highest insect abundance such as tent caterpillar infestations and cicada cycles. Cicadas are resilient to high temperatures and habitat changes associated with declining water tables, thus may provide greater food resources periodically.	
2. Predators	Are important predator populations expected to change?	Raptors may be an important predator during migration and upon arrival on wintering grounds (Hector 1985 in Hughes 1999). Snakes, mammals, and avian predators depredate nests (Hughes 1999). Raptors may be an important predator during migration and upon arrival on wintering grounds. Snakes, mammals, and avian predators depredate nests. Wide variety of predators and climate influences, thus probably no overall change in predation rate.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Use of other bird's nests for eggs, but brood parasitism is only facultative in this species and seems to only occur rarely.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Numerous diseases and parasites have been documented, but no information indicating significant negative effects on populations. Seldom subject to brood parasitism by brown-headed cowbird (*Molothrus ater*) as nesting duration is short. Nests are occasionally parasitized by Brown-headed Cowbird (*Molothrus ater*), but generally not successful because cuckoos have a short nesting duration (Hughes 1999). Also lays eggs in the nests of other conspecifics or other species, but there are few records (Hughes 1999).	**0**
5. Competitors	Are populations of important competing species expected to change?	No information on competitors.	**0**

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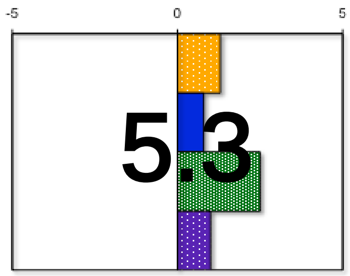


Mexican Spotted Owl
(*Strix occidentalis lucida*)

SUMMARY

Spotted owls were assessed to be vulnerable to declines associated with future climate change. Significant vulnerabilities are related to upward shifts of forest habitats, physiological thresholds, and fluctuations in prey populations. Management with climate change will depend on balancing various risks related to fire severity, cool microsites, drought mortality of trees, and factors that affect prey populations.

Introduction

Mexican spotted owls are geographically isolated and genetically distinct from the other two spotted owl subspecies, northern and California. The Mexican spotted owl was listed as a threatened species in 1993 (USFWS 1995). It is a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). Main threats to current populations have been identified as habitat alteration from silvicultural practices and catastrophic wildfires.

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

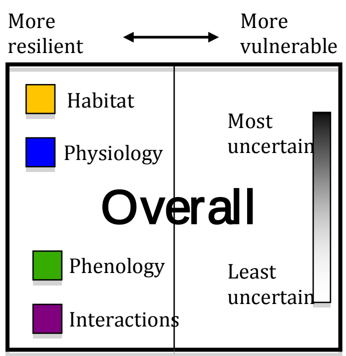
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	29%
Physiology	**0.8**	0%
Phenology	**2.5**	50%
Interactions	**1.0**	40%
Overall	**5.3**	27%

Figure Key



Other threats and interactions with climate

There have been considerable changes in fire regimes at Fort Huachuca since the 1870s (Danzer et al. 1996). Fires of varying intensities were common in the past, but fire-free intervals have been lengthened considerably through fire suppression (Danzer et al. 1996). With fewer fires, recruitment has increased for shade-tolerant species such as Douglas fir and Gambel's oak. Additional changes in forest composition occurred when the more accessible slopes were logged (Danzer et al. 1996). While fire suppressed forests are suitable habitat for Mexican spotted owls, they are also more prone to high intensity stand-replacing fires, which will reduce suitable habitat for long periods. In the short term, owls remained on their territories and reproduced successfully following large fires in California, Arizona, and New Mexico (Bond et al. 2002), thus this species may be at least partly resilient to increasing fires. Conversely, interactions of fire with drought mortality in trees and invasion by grass species will likely shift fire regimes and habitats outside the range of suitability for spotted owls. Hotter temperatures, especially during dry periods, will increase ignition of fuels. Variable rainfall (i.e., wet years followed by dry years) will also encourage fire. Fires more frequently occur at lower elevations where precipitation is lower and there is the additional interaction of invasive grass species that favor frequent fire. Fires from these elevations can spread upslope.

Research Needs
Although studied to some extent, more detailed study and risk assessment are needed to assess how to best maintain suitable dense forest habitats as climate warms. This risk assessment should include landscape variables such as topography, adjacent vegetation types, and proximity of weed infestations.

Management Options
Management related to fuels and fire is likely important to this species, particularly because a number of vulnerabilities to climate change are habitat related. Prescribed fire or thinning may be helpful to increase resilience of forests to stand-replacing fires that can encourage conversion to other vegetation types and resilience of large trees to drought mortality. Protection of cool microsites and canyon bottoms will be important as temperatures increase. Management that enhances prey populations through changes in forest debris or encourages understory vegetation may also enhance resilience.

Restrictions in activities during breeding are common management actions for this species. Changes in breeding timing should be anticipated and restrictions altered accordingly.

Habitat: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Mexican spotted owls occur mostly in montane forests and canyons. Preferred forest types include ponderosa pine, mixed-conifer, and pine-oak forests with highest densities in mixed-conifer forests (USFWS 1995). At Fort Huachuca, Mexican spotted owls occur in canyons with ponderosa pine and Douglas fir although they probably also use oak woodlands particularly in winter. Coniferous forest types are limited to higher elevations (>7000 ft) of Fort Huachuca where precipitation is higher (Wallmo 1955). Following wildfires, most owls remained on their territories and reproduced successfully (Bond et al. 2002). Projected changes in climate indicate that mixed conifer and pine-oak habitats will be reduced as they shift to higher elevations.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	May forage in a wider range of habitats than are usually described for nesting (Ganey and Balda 1994). Coniferous forests in the region are likely to be reduced.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Nests are built in large trees or in cliffs within closed-canopy forests or canyons. The most common nest sites are old raptor nests and witches brooms (USFWS 1995). Availability of nest sites within forests is not expected to change.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**

Habitat: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Old growth forests with large trees and complex structure are preferred (Fletcher and Hollis 1994). Use of these microsites may be to escape high temperatures (Ganey et al. 1993). Favorable microsites may be reduced with tree mortality associated with drought, particularly in dense stands.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Adults generally have high site fidelity with most dispersal by juveniles of both sexes (USFWS 1995). Some owls also migrate to lower elevations in winter. The recovery plan indicates owls may have very few movements to adjacent habitat patches, but are more likely to disperse within patches (USFWS 1995). Territorial individuals often have high site fidelity, but juveniles of both sexes may disperse relatively long distances.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Although observed, most individuals do not migrate or use specific transitional habitats.	**0**

Physiology: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Arizona is in the southern portion of the distribution, but also occur farther south in northern and central Mexico. Mexican spotted owls may be less able to dissipate heat than great horned owls and thus select cooler microsites (Ganey et al. 1993). Fairly intolerant of high temperatures. Predicted increases in temperatures, particularly during summer, may exceed thresholds.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Starvation and predation are the most common mortality causes (USFWS 1995). No records of large mortality events associated with storms or fire were found.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Primarily nocturnal when temperatures are cooler. Activities not likely to be limited.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies known.	**0**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Probably initiate breeding based on photoperiod with some flexibility with temperature.	**0**

Phenology: Mexican Spotted Owl (*Strix occidentalis lucida*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Eggs are laid in late March, hatch at the beginning of May with young fledging around mid-June (Ganey 1988). Breeding and nesting likely timed to prey abundance, which is likely to have changes in peak abundance related to temperature.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding is not distant from nesting locations, but not in direct response to resource levels.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Two eggs are most commonly laid though most pairs do not breed every year (Ganey 1988).	**1**

Biotic Interactions: Mexican Spotted Owl (*Strix occidentalis lucida*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Spotted owls eat a wide variety of prey, but a large portion of the diet is from small to medium-sized rodents. A review of diet studies indicated that in the Fort Huachucua region, the most common prey item was *Peromyscus* species followed by woodrats, which by weight were the most important component of the diet (USFWS 1995). Small rodent abundance generally fluctuates with rainfall and may be reduced by higher temperatures and more variable rainfall.	**1**

Biotic Interactions: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Predators	Are important predator populations expected to change?	Predation is probably low in adults. Preyed upon by a variety of raptors, especially great horned owls. No expected changes in predation rates.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Little information is available on disease in spotted owls (USFWS 1995).	**0**
5. Competitors	Are populations of important competing species expected to change?	Known to compete with barred owls, but do not occur in this region.	**0**

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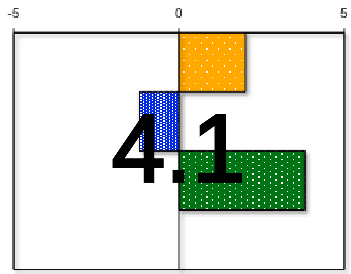


Elegant Trogon
(*Trogon elegans*)

SUMMARY

Currently an uncommon migrant in Arizona, warmer winters may improve conditions for the elegant trogon, which could become a year round resident at Fort Huachuca. Although abiotic conditions may improve, suitable forest habitats are vulnerable to declines and overall populations are vulnerable to decline. Management related to fire and invasive grasses will be important to preservation of suitable habitats. The possibility of year-round residency should also be anticipated in management plans.

Introduction

The elegant trogon has no federal status, but is a USFS sensitive species and a species of greatest conservation concern, Tier 1B, in Arizona (AGFD 2006). It is also designated as a species as risk (SWESA 2006). Breeding distribution in the U.S. is limited to a small area in southern Arizona and New Mexico. Overall population trend seems to be stable, but may have large annual fluctuations in Arizona, although these may be related to census methods and consistency (Kunzmann et al. 1998).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)

- Decreased annual rainfall in Central America (Magrin et al. 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin et al. 2007)

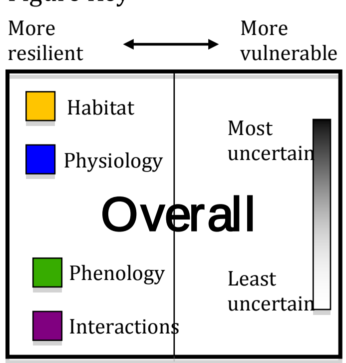
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.0**	14%
Physiology	**-1.2**	50%
Phenology	**3.8**	25%
Interactions	**0.0**	60%
Overall	**4.1**	32%

Figure Key



Other threats and interactions with climate

Fires can occur frequently where forests are adjacent to grasslands. Wildfires are expected to become more frequent with projected increases in temperature (Rogers and Vint 1987, Swetnam and Betancourt 1990). In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence when years of high rainfall are followed by dry/hot conditions creating conditions conducive both to fire ignition and fuel accumulation. Buffelgrass (*Pennisetum ciliare*) is a native perennial of Africa introduced for livestock grazing that is rapidly expanding and becoming increasingly problematic in the Sonoran

Desert. Buffelgrass promotes a frequent high severity fire regime, which encourages further growth of these grasses while negatively impacting native desert vegetation (Williams and Baruch 2000).

Research Needs

Many life history aspects are not well known for this species and there have been few studies outside Arizona (Kunzmann et al. 1998). Basic life history information related to energetics and migration would be particularly relevant to climate change.

Management Implications

The potential for increasing impacts from invasive African grasses and increasing fires warrants inclusion in management planning and implementation of preventative actions. Prescribed fires and mechanical treatments, as well as invasive grass control, may increase forest resiliency to stand-replacing wildfires that would be likely to reduce habitat availability.

Like many secondary cavity nesters, elegant trogons may be limited by cavity availability. A study by Hakes (1983) showed trogons did not use any of 30 nestboxes in the Huachuca Mountains over 4 years. Nest boxes are not likely to alleviate this scarcity although competition would be reduced if competing species use nest boxes preferentially.

Populations of elegant trogons in southeastern Arizona are thought to be migratory because of limitations in cold tolerance to winter temperatures. Winter temperatures are projected to increase and year-round populations occur in nearby northern Mexico. Thus, there is some potential that elegant trogons may begin to use habitats at Fort Huachuca year round. Prediction of shifting populations is supported by records of nesting in 2008 and 2009 at Montezuma Castle National Monument, far north of previous records. Mitigation measures based on assumption of seasonal presence, such as activities that are restricted by date, would then need to be reconsidered.

Habitat: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In Arizona, reported to breed regularly in Atascosas, Chiricahua, Huachuca, and Santa Rita mountain ranges (Kunzmann et al. 1998). In U.S., breeding habitat includes high elevation pine and pine-oak forests and Arizona sycamore (*Platanus wrightii*) riparian woodland (Hall 1996 in Kunzmann et al. 1998). In Arizona, abundance is greatest in canyons with riparian vegetation dominated by sycamores, pinions, junipers or pines (Hall 1996 in Kunzmann et al. 1998). Upland areas also used and are often dominated by mesquite (*Prosopis* sp.) (Hall and Mannan 1999). Riparian areas and associated vegetation are likely to decline with higher temperatures and reduced winter precipitation.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Some records of overwintering in Arizona, but generally winter in Mexico and Central America where trogons are also year-round residents (Kunzmann et al. 1998). No information on what region U.S. individuals migrate to. Semiarid pine-oak and scrub forests to high elevation pine forests in Mexico and Central America (Kunzmann et al. 1998). High elevation forest types are expected to shift upslope, reducing area and woody species in semiarid regions will likely decline with higher temperatures and increased fire occurrence.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	They nest primarily in abandoned woodpecker cavities, preferably in large sycamores, but also in oaks or pines within 300m of water (Kunzmann et al. 1998). Old reports of this species nesting in banks but Kunzmann et al. (1998) found no reliable evidence to support this. Large trees are vulnerable to fire, taking a long time to regrow, and declining water tables	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**

Habitat: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Higher nest success was observed in nests in cavities in trees with larger diameters and height of vegetation to south of nest tree was greater (Hall 1996 in Kunzmann et al. 1998). Dense understory vegetation was also associated with greater reproductive success (Hall and Mannan 1999). Dense understory vegetation is expected to remain unchanged within suitable habitats.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Both sexes are highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Most of the US population migrates in winter, but unknown migration routes and distance. Regardless, it likely uses transitional habitats between winter and breeding grounds.	**1**

Physiology: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Members of the Trogonidae family are not tolerant of cold temperatures, which likely limit their northern distribution (Kunzmann et al. 1998). When migrant trogons arrive in Arizona to breed, mountain ranges used by this species are nearly free of snow (Kunzmann et al. 1998). Low resting metabolic rate of a related species (*Trogon rufus*) relative to other bird families may reflect low ability to generate heat (Kunzmann et al. 1998). Warmer winters may improve winter conditions, although currently no trogons present in Arizona year-round. Fort Huachuca, therefore, may become more suitable for wintering birds. Use of semi-arid regions indicates they may be fairly tolerant of hot conditions, but no data available.	**-1**

Physiology: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	No information on mortality related to storms, but often associated with mortality in birds. Central America (wintering grounds) already subject to increased hurricanes, heavy rains, and dry periods. Drought suggested as a factor behind low population numbers in the 1950s. Increasing drought duration is projected for the Southwestern United States.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	No limitations known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	This species seems to have flexible migratory behaviors, which may help it cope with regional variability in resources. Extent of this flexibility in the population, however, is unknown.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic (relative to other vertebrates).	**0**

Phenology: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Cues not known. Likely a combination of internal and external signals.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Nesting in Alamos in the Mexican state of Sonora is reported to be timed with summer rainy season (Kunzmann et al. 1998). In Arizona, breeding initiation dates reported variable among pairs in a two year study, with nests begun in May, June, and July (Hall and Karubian 1996). Timing of breeding to rainy season may be correlated with insect abundance. Timing and quantities of summer precipitation in the future are mostly unknown, but likely to become more variable.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration and initiation of breeding are separated geographically and temporally.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	In Arizona, most pairs rear one brood per season (Kunzmann et al. 1998).	**1**

Biotic Interactions: Elegant Trogon (*Trogon elegans*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Wide variety of foods taken, but mainly fruit, grasshoppers, and other insects (Kunzmann et al. 1998). Less likely that all food resources will be synchronously reduced or enhanced.	**0**
2. Predators	Are important predator populations expected to change?	Predation on adults not well documented and may be uncommon (Kunzmann et al. 1998), but likely includes squirrels and raptors. Nest predation is fairly rare (Hall and Kurubian 1996) and is likely opportunistic by a variety of species.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	They require other species to excavate cavities. Often nest in cavities excavated by woodpeckers. No evidence that cavity creating birds will all decline.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases that cause widespread mortality.	**0**
5. Competitors	Are populations of important competing species expected to change?	Intra-specific competition observed in apparent competition for nest cavities. Both males and females defend nest cavities against other species of primary and secondary cavity nesters (e.g., Sulphur-bellied Flycatcher, Northern Flicker, Eared Trogon, screech owl) (Kunzmann et al. 1998). Competes with other species for cavities, but no evidence that this is limiting for trogon populations.	**0**

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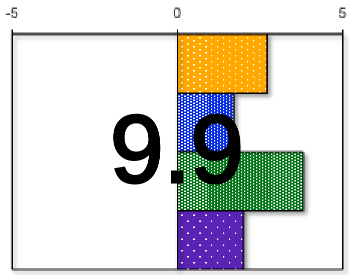


Southwestern Willow Flycatcher (*Empidonax trailii extimus*)

SUMMARY

The Southwestern willow flycatcher is associated with riparian habitats, which have been largely degraded or lost in the Southwest. Climate change is expected to exacerbate these conditions. Besides habitat use, we found vulnerability to declines associated with climate change was related to timing of floods and insect emergence, thermal tolerances, and brood parasitism by brown-headed cowbirds. Management of water inputs for riparian habitats will be important along with control of exotic plants although impacts from Fort Huachuca will be limited when considering the broad scope and scale of threats.

Introduction

The Southwestern willow flycatcher is one of four currently recognized subspecies and recognized as federally endangered (USFWS 2003). Southwestern willow flycatchers do not occur on Fort Huachuca, but the nearby San Pedro River is designated critical habitat for the southwestern willow flycatcher.

Fort Huachuca climate and projections

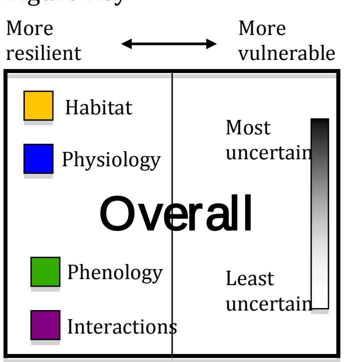
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin et al. 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin et al. 2007)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.1.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.7**	29%
Physiology	**1.7**	50%
Phenology	**3.8**	50%
Interactions	**2.0**	20%
Overall	**9.9**	36%

Figure Key



Other threats and interactions with climate
Loss and degradation of dense riparian areas is generally cited as the main cause of populations declines (USFWS 2003). Degradation has been related to invasion by invasive non-native species, changing hydrology, water diversions, and livestock grazing (USFWS 2003). Climate change in the region is likely to exacerbate a number of these conditions including drying of riparian areas and invasion by non-native species, particularly salt cedar. Willow flycatchers will nest in riparian areas dominated by salt cedar. It is speculated, however, that salt cedar reduces reproductive success in hotter climates because of reduced shading. Depending on the strength of this mechanism, warming in the region may increase the more drought tolerant salt cedar while also increasing the threat of thermal limits on

nesting. Riparian stands with >90% exotics are considered unsuitable (USFWS 2003). Changes in flood regimes also may impact this species depending on timing.

Research Needs

A wide variety of topics have been investigated for this species. Thermal aspects of their biology and habitat will become increasingly important and need more thorough study. In addition, impacts of control measures for exotic plants, such as introduced bio-control agents, on willow flycatchers are not well known.

Management Implications

Willow flycatchers breed on the San Pedro River and likely seldom encounter habitats on Fort Huachuca. Activities that affect hydrology have the potential to impact habitats on the San Pedro River. Water conservation measures, many of which are already implemented, are important to protecting area water tables. Vegetation management can also affect run-off. In light of the multitude of threats including increasing droughts, declining water tables, and expansion of exotic plants, riparian habitats will likely decline. The ability of management actions on Fort Huachuca to mitigate climate change threats to the willow flycatcher is limited.

Habitat: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Often associated with shrubby and wet habitats (Sedgwick 2000). Nests in flooded areas with willow dominated areas, but also with non-native saltcedar and Russian olive. Expected reductions in water availability due to high evaporative losses in the Southwest and increasing demands from growing human populations. Lower water tables will favor saltcedar over willow. Generally, does not occupy areas dominated by exotics (Sogge and Marshall 2000), but can successfully nest in some saltcedar-dominated habitats (Sogge et al. 2006). Fire may increase shrubby habitats, but report by Paxton et al. (1996) noted that fire destroyed habitat.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Winters in southern Mexico, Central America and northern South America (Sedgwick 2000). Wintering habitat dominated by shrubs in proximity to water. Occur mainly in lowland areas where agricultural and ranching activities occur (Lynn et al. 2003). Drying in these regions will likely decrease habitat availability.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Shrubs and small trees used for nesting substrates. Additionally, willow flycatchers will not nest if water is not flowing (Johnson et al. 1999). Stream flows expected to be reduced, particularly later in the year when nesting occurs.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**

Habitat: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Increased shrub cover associated with reproductive success (Bombay et al. 2003). Low fecundity and starvation in nestlings associated with low snowpack and drying of marshes in Oregon (Sedgwick 2000). Flooding may be associated with reduced predation by mammalian predators (Cain et al. 2003). Flooding may increase with warmer winter temperatures, but expected lower overall water output and advancement of flood pulse may shift pulse too early to benefit nesting. Saltcedar, while used for nesting, may be limiting for nesting in hotter climates, because it does not provide needed shade (Hunter 1988). Decreased streamflow will likely drop water tables and favor saltcedar over willow, which will be detrimental to the extent that saltcedar decreases quality. This decrease seems likely because of the lack of microclimate advantage in saltcedar, which will be more critical as temperatures increase.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile. Fairly high site fidelity to breeding grounds (Sedgwick 2000), but known cases of recolonization of habitats. Likely has a good capacity to shift with changes in habitat.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Long distant migrant through a variety of habitats.	**1**

Physiology: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Decline of willow flycatchers associated with spread of tamarisk, which may not have the thermal protection of broadleaf shrubs (Hunter 1988), though nests successfully in tamarisk in many areas (Sogge et al. 2006). Unknown if similar limitations for adults. Moist and shady microclimates may be associated with relatively late nesting and accompanying hot temperatures (Sogge and Marshall 2000).	**1**

Physiology: Southwestern Willow Flycatcher (*Empidonax traillii extimus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Not expected to be exposed to greater storms for interior migration routes used by SW willow flycatcher. No extreme weather mortality recorded (except for nestlings- see Habitat Question 5).	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	No known limits to diurnal activity. Activity may be somewhat buffered by occurrence in moist environments.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Photoperiod likely important for timing migration. No change in cue expected.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Short nesting season thought to be limited by short duration of resource availability (Sedgwick 2000). Insects may emerge earlier or become more variable with more variable rainfall.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Potentially large difference in migration cues and insect emergence- not tightly related in space or time.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Generally single brooded with a fairly short breeding season (Sedgwick 2000).	**1**

Biotic Interactions: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Willow flycatchers are primarily insectivorous (Sedgwick 2000). Years of low rainfall associated with reduced food supplies and lower reproductive success. Dry periods and rainfall variability both expected to increase.	**1**
2. Predators	Are important predator populations expected to change?	Various predators (Sedgwick 2000). No overall changes in predation rates expected.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Nests are parasitized by brown-headed cowbirds, which mostly cause failure of the genetic young. Currently willow flycatcher reproduction occurs relatively late, which does not allow for breeding attempts too early from cowbird brood parasitism (Robinson et al. 1995). The shorter migration distance in cowbirds will likely allow cowbirds to keep pace with any advancement in breeding by willow flycatchers. In addition, cowbirds possess a number of traits that will incur resilience to climate change.	**1**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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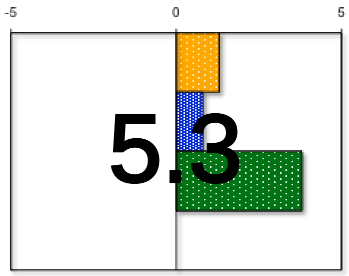


Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)

SUMMARY

The buff-breasted flycatcher was assessed to be vulnerable to population declines associated with future climate change. Fire is an important factor in habitat suitability for this species although beneficial variables, such as frequency and intensity, are unknown and influenced by climate. Management related to prescribed burning and post-fire rehabilitation will likely be important in sustainable populations of buff-breasted flycatcher.

Introduction

Northern buff-breasted flycatcher has retreated from formerly occupied habitats in Arizona (Bowers and Dunning 1994). It currently breeds at Fort Huachuca in the summer and is designated as Tier 1B in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) as well as a species at risk (SWESA 2006). The rarity of this species in the U.S. also attracts birders to Fort Huachuca.

Fort Huachuca climate and projections

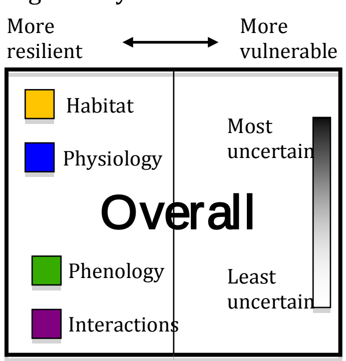
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin et al. 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin et al. 2007)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	29%
Physiology	**0.8**	50%
Phenology	**3.8**	25%
Interactions	**0.0**	60%
Overall	**5.3**	41%

Figure Key



Other threats and interactions with climate
Formerly, this species also occurred in central Arizona (Bowers and Dunning 1994). Declines during the past century are thought to be due to fire suppression and overgrazing of mountain meadows (Bowers and Dunning 1994). Buff-breasted flycatchers have also been found to be associated with areas with evidence of high severity wildfires suggesting that high severity fires may be needed to provide preferred habitat (Conway and Kirkpatrick 2007). Although cowbird populations could change in the future, brood parasitism may be rare because of nest placement (Bowers and Dunning 1994). Overall population trends in the U.S. are unclear with declining trends from some survey areas (Conway and Kirkpatrick 2007), but increases into new or historic habitats in others (Bowers and Dunning 1994, Kirkpatrick et al. 2007).

Research Needs
Despite being on the edge of the species' distribution, most studies are from Arizona. Studies within more central portions of the range may provide better

information on fitness components and habitat requirements. Interaction of habitats with fire is thought to be important, but is not well studied. Further study would identify fire frequencies and intensities that are important to sustainable populations.

Management Implications

Foraging habitats are thought to improve with clearing of the understory such as by low severity fires (Martin and Morrison 1999). Other studies have suggested more intense fires are needed to provide sustainable habitats (Conway and Kirkpatrick 2007). The degree of fire severity seems to be an important variable in habitat suitability, but time since fire may also play a role. It has been suggested that prescribed fires will be unable to improve habitat for this species and fires of higher intensity may be needed (Conway and Kirkpatrick 2007). But high intensity wildfires that will be encouraged by very hot conditions and years of variable rainfall are likely to result in high tree mortalities and loss of habitat, thus the relationship seems to be a matter of degree. Prescribed fires or mechanical treatments, although they may not directly enhance habitats, may help prevent very large and intense wildfires that would almost certainly be detrimental. Forests that have regrown following burning may be important habitats, thus post wildfire conditions and revegetation are important management considerations.

Habitat: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies open oak/pine woodlands and riparian areas at higher elevations (Bowers and Dunning 1994). In Arizona, often found in pine forests with a sparse oak understory (Martin and Morrisson 1999). Oak woodlands and riparian areas will likely be reduced by higher temperatures, upslope shifts, and increased fires.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Migratory in northern part of its range, including Arizona. Winter habitats in Mexico similar, but may also move downslope into canyons and more low-lying riparian areas (Bowers and Dunning 1994). Wintering grounds in northern Sonora likely subject to the same threats.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Arizona nests are usually in a conifer with a protective overhanging branch or piece of bark (Bowers and Dunning 1994). Not expected to change within suitable woodlands.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**

Habitat: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Reproductive success is higher farther from edges (Martin and Morrison 1999). Reduced understory vegetation may enhance foraging opportunities. Unclear how climate may influence landscape patchiness or understory vegetation.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Arizona populations are migratory through northern Mexico.	**1**

Physiology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	None known. Most of this species range is in Mexico and Central America.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	None known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Not known, but likely a combination of internal and external signals.	**0**

Phenology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Nest during the (current) dry season in Arizona, May through June (Bowers and Dunning 1994), but no known consequences for reproduction. Availability of aerial insects is likely important to nesting and emergence is related to temperature.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration timing and cues distant from breeding.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive period.	**1**

Biotic Interactions: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats aerial insects but also ants, grasshoppers, and spiders (Bowers and Dunning 1994). No overall changes anticipated.	**0**
2. Predators	Are important predator populations expected to change?	Likely various. No overall change in predation levels.	**0**

Biotic Interactions: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Symbionts	Are populations of symbiotic species expected to change?	None	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known. Not prone to brood parasitism.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known, although possibly other flycatchers although those are likely similarly vulnerable to climate change.	**0**

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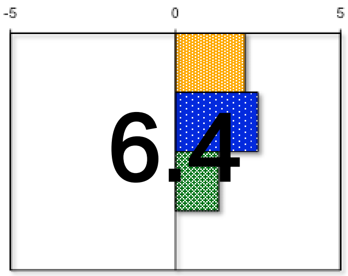


Arizona Shrew
(*Sorex arizonae*)

SUMMARY

Arizona shrews were assessed to be vulnerable to declines associated with projected changes in climate. Vulnerability is related both to predicted physiological effects and their association with mesic environments, which are likely to dry with increased temperatures. Preservation of riparian habitats and water tables will be key management areas.

Introduction

The Arizona shrew is known to occur at Fort Huachuca. Little information is available on this species, but there is potential for it to occur in more locations than those currently identified. Currently it is only known from a few mountain locales in southeast Arizona and southwest New Mexico and the Sierra Madre Occidental in Mexico. It is a U.S. Fish and Wildlife Service (USFWS) species of concern (last reviewed in 1994) and species at risk (SWESA 2006). Arizona shrew is designated as Tier 1B in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and as sensitive by the USDA Forest Service.

Fort Huachuca climate and projections

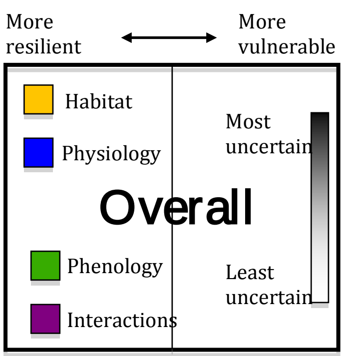
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**2.1**	57%
Physiology	**2.5**	33%
Phenology	**1.3**	75%
Interactions	**0.0**	60%
Overall	**6.4**	55%

Figure Key



Other threats and interactions with climate
Potential threats to this species include removal of downed woody debris through understory clearing and firewood collection, intense ground-burning fires that remove ground structure and possibly livestock grazing and development of recreation sites in Arizona (NatureServe 2009). Threats to understory debris are expected to increase as more fires burn with warmer temperatures and more variable precipitation regimes. Increases in invasive grasses may also carry more fires from lower elevations.

Research Needs
Even basic life history traits are not well studied in this species. It is unknown how low severity fires may impact this species and its habitats. In addition, it is unknown how different fuel and fire management techniques, such as mastication or prescribed fire, affect this species.

Management Implications

Activities that disturb or remove ground cover, especially in canyons or riparian areas are likely to negatively impact this species, but are generally well regulated because of the concentration of biodiversity in these areas. Protection of water sources and water tables will be important. Riparian areas may be particularly prone to drying with warmer temperatures and increased high severity wildfires. Activities that increase fire occurrence from surrounding areas could contribute. Management efforts to reduce forest fuels and manipulate fire severity, although increasing resiliency of some forest elements, may also reduce downed woody debris that this species is associated with. Even low severity fires could remove important forest debris although patchy burning patterns may leave habitat intact. On the other hand, fire suppression efforts will eventually increase the risk of higher severity fires that will reduce availability of unburned patches and potential refugia for this species when fires do burn. Management plans should include post-fire actions that can rehabilitate or protect shrew habitat.

Habitat: Arizona Shrew (*Sorex arizonae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in mesic environments, such as riparian edges, in dense oak woodlands or conifer forest although may also be adjacent to dry environments that support agave and cactus (BISON-M). Also associated with boulders and logs. One study in Garden Canyon, Arizona, found this species in riparian habitats above 1500m (Simons et al. 1990). Generally found in canyon bottoms and often near springs or along dry creek beds. Riparian edges, dense woodlands are likely reduced by warming and increased fires.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Desert shrews (*Notiosorex crawfordi*) build nests of bark and leaves in protected locations for reproduction and torpor (NatureServe 2009). Specificity of materials for this species is unknown thus effects are unknown.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**

Habitat: Arizona Shrew (*Sorex arizonae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Forage in and under litter (BISON-M), but no known relationship between litter quantity and foraging success. Litter should remain unchanged in suitable habitats.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Male shrews of other species may wander widely (Hawes 1977), but dispersal in this species unknown and potentially limited by mesic environments. Small *Sorex* generally have high dispersal abilities and colonization rates (Taylor 1998). Limited information. Dispersal is possibly sex biased and limited by patchiness of mesic habitats.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Arizona Shrew (*Sorex arizonae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Soricines (Soricidae) are thought to have low tolerance for high ambient temperatures (Taylor 1998). Shrews generally have high body temperatures and low critical thresholds. Likely to be exceeded in these habitats, where temperatures are already high.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Arizona Shrew (*Sorex arizonae*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Desert shrew uses torpor, but unknown for this species and generally not seen in Soricidae. Buffered from extremes to some extent by use of mesic and fossorial habitats.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Desert shrew stores paralyzed insects in food caches, but only in the short term (BISON-M). No flexible strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Very high metabolic requirements.	**1**

Phenology: Arizona Shrew (*Sorex arizonae*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	None known.	**0**

Phenology: Arizona Shrew (*Sorex arizonae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Breeds in the spring, but unknown resource peaks.	**0**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Active throughout the year (NatureServe 2009). No large separation between events and cues.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	No information, but likely to have one breeding event per year.	**1**

Biotic Interactions: Arizona Shrew (*Sorex arizonae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Shrews eat insects, spiders, and other invertebrates (BISON-M). No overall changes in invertebrates are expected.	**0**
2. Predators	Are important predator populations expected to change?	Likely various. No overall changes in predation levels are anticipated.	**0**

Biotic Interactions: Arizona Shrew (*Sorex arizonae*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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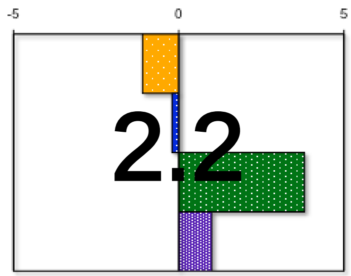


Cave Myotis
(*Myotis velifer*)

SUMMARY

Vulnerability of this species to population declines is increased by expected effects of climate change. This species both migrates and hibernates, two activities associated with timing changes that may lead to mismatches with other events such as insect emergence or suitable breeding conditions. Timing relationships are complex, thus eventual outcome in the future is unknown and periodic monitoring is recommended. Roosts and open water sources are important elements for this species that could be affected and should be considered in management planning.

Introduction

Cave myotis is a federal species of concern (since 1994) and a species at risk (SWESA 2006) that occurs on Fort Huachuca. The U.S. Forest Service also identifies it as sensitive. Despite being widespread, this species is threatened locally, particularly in western portions of its range.

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)

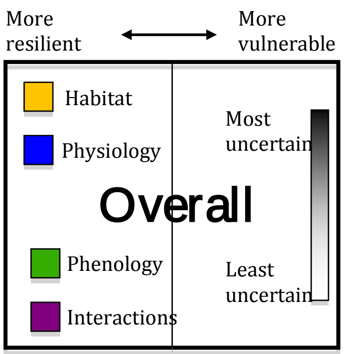
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-1.1**	14%
Physiology	**-0.2**	33%
Phenology	**3.8**	25%
Interactions	**1.0**	60%
Overall	**2.2**	32%

Figure Key



Other threats and interactions with climate

Patchy distribution of this species may be due to its reliance on caves, which are geographically limited. Recent population declines in cave myotis are thought to be related to local habitat loss (BISON-M). Additionally, cave myotis, like many other bats, is vulnerable to disturbance at roosts, especially maternity roosts.

Research Needs

More information on suitable roost sites at a local level is needed as these features affect species' presence. The threat of white-nosed fungus for Arizona bats will be important to the species overall, but this disease has not been detected in Arizona. This disease is associated with cool temperatures and may threaten higher elevation sites on Fort Huachuca, but almost all aspects of this disease need more study. Importance of various foraging habitats is not well known, thus critical habitat elements are difficult to assess. Examination of how populations may be affected by drought conditions will be critical to predicting climate change effects and are not known in this species.

Management Implications

Most cave myotis winter outside of Arizona and their affinity for cool, moist hibernacula is unlikely to increase winter presence at Fort Huachuca in the future. Maternity roosts may become more limited and suitability of current roosts may be altered over time. Potential roost sites should be checked periodically for species presence. Some monitoring of populations is warranted, as identified phenological vulnerability will have an uncertain outcome on populations because of interactions with resources are more complex than can be evaluated here. Flexibility in migratory behaviors will likely help this species cope with changes on a broad scale, but will increase likelihood of population changes on Fort Huachuca and other parts of Arizona.

Habitat: Cave Myotis (*Myotis velifer*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in various desert grassland habitats, but also been found in pinyon-juniper woodland (BISON-M). Grasslands may increase with warmer temperatures.	**-1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	May move to southwestern Mexico for winter (BISON-M). Assume similar habitats to breeding.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Roosts in caves and mines, occasionally buildings or bridges. Often found near the entrance (BISON-M). Caves and mines will not change with climate.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Prefers moist caves for hibernation (NatureServe 2009). In Arizona, winter roosts are in moist caves above 6000 feet. Cave availability not expected to change (but see Physiology Question 1).	**0**

Habitat: Cave Myotis (*Myotis velifer*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	In Arizona, often in vicinity of water sources (Hoffmeister 1986). It is likely that these features are important for successful foraging and likely to decline with warmer temperatures.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Mostly migratory in Arizona although migratory behavior seems somewhat flexible (NatureServe 2009).	**1**

Physiology: Cave Myotis (*Myotis velifer*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Ranges from the southwestern and central U.S. into Central America. Preferred hibernaculum temperature is 8 to 9° C (Hoffmeister 1986). Most bats in Arizona migrate to hibernate, but for those that remain seek out moist, cool habitats (Hoffmeister 1986). Not known if warmer, drier conditions will exceed thresholds, but they may. Rely on moist, cool caves for hibernation, which will warm and lose moisture with increasing temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Cave Myotis (*Myotis velifer*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known. Buffered from extremes in hibernaculum.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Nocturnal. No expected changes in activity.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Sperm is stored over winter, which may maintain breeding with population and resource fluctuations. In addition, migratory behavior may be flexible (NatureServe 2009)	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Cave Myotis (*Myotis velifer*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Emergence from roosts is later after sunset in summer than spring (NatureServe 2009) and is apparently signaled by exterior light levels (Hoffmeister 1986).	**0**

Phenology: Cave Myotis (*Myotis velifer*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Young born mid to late June in Arizona and females leave maternity colonies in August (NatureServe 2009). Favorable weather conditions and insect peaks are likely to change timing.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Bats in Mexico moved to higher elevation caves to hibernate (NatureServe 2009), perhaps to take advantage of colder conditions. Emergence from hibernation and migration occurs far from insect emergence and feeding of young.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Cave Myotis (*Myotis velifer*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Insectivorous and likely opportunistic (NatureServe 2009). Overall prey levels not expected to change.	**0**

Biotic Interactions: Cave Myotis (*Myotis velifer*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Predators	Are important predator populations expected to change?	Likely various. No overall changes in predation expected.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Hibernates in large clusters and occupies roosts with other species (NatureServe 2009). May have thermal advantages, but no known changes in clusters.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Single bat found in May 2010 with white-nose syndrome from western Oklahoma was from this species (USFWS news release: 19 May 2010). This is the first reported occurrence of the disease in this species and the first from west of the Mississippi although no associated mortality was reported. Transmission may increase if individuals are restricted to fewer suitable roosts.	**1**
5. Competitors	Are populations of important competing species expected to change?	*Myotis lucifugus occultus* may exclude this species from suitable habitat (BISON-M). No known changes in this species although likely to be similarly vulnerable.	**0**

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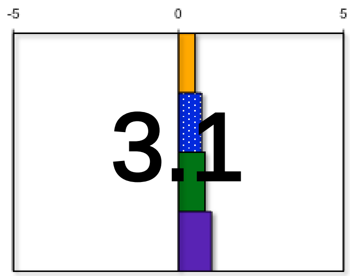


Lesser Long-nosed Bat
(*Leptonycteris yerbabuenae*)

SUMMARY

Lesser long-nosed bats were assessed to have moderate vulnerability to declines related to global climate change. Vulnerability is increased by their reliance on quantity and timing of flowering of a limited number of plant species, while resilience is incurred by flexible migratory behaviors and probable resilience of forage plant populations to increasing temperatures. Unfortunately, changes in climate are expected to exacerbate current threats making conservation of this species more challenging. Current critical threats of roost disturbance and loss of foraging habitats will likely be increased through growing international border activity and the interactive effects of fire occurrence and non-native invasive grasses. Additionally, changes in the timing of bat presence on Fort Huachuca should be anticipated and integrated into planning.

Introduction

Lesser long-nosed bats were listed in 1988 as endangered under the subspecies *Leptonycteris curasoae yerbabuenae*. Originally they were listed as *Leptonycteris sanborni* (Sanborn's bat), but were also sometimes identified as *Leptonycteris curasoae*. Lesser long-nosed bats inhabit the desert scrub habitats in Arizona and northwestern Mexico and are nectarivorous, closely associated with paniculate agaves and columnar cactus. Agaves are present on Fort Huachuca and are primarily Palmer's agave (*Agave palmeri*) with some Parry's agave (*Agave parryi*).

Numbers of lesser long-nosed bats have increased in recent years or may not have been as low as reported when first listed. The five year review by the U.S. Fish and Wildlife Service (USFWS) suggests downlisting the status to threatened, because current populations appear to be stable or increasing, but the review also acknowledged that threats still exist particularly for roosts, impacts in Mexico, and vulnerability of foraging plants to fire and invasive species (USFWS 2005). Populations are migratory from Mexico where there are also resident populations of this species. Occurrence of two female demes complicates population dynamics and species requirements (USFWS 2005). In this account we focus on the migratory group that lives in Arizona and south to southern Sonora. Only three maternity roosts and approximately 40 roosts overall are known in the U.S. (USFWS 2005).

Lesser long-nosed bats arrive in late summer at Fort Huachuca, Arizona after giving birth and before continuing their migration south. Bats in this region may arrive from maternity roosts in western Arizona and/or travel north from the Sierra

Madre Occidental (Fleming and Nassar 2001). Over the past 10 years, lesser long-nosed bats have increased on Fort Huachuca from a few hundred to more than 14,000 (USFWS 2005). While some increases in numbers have been attributed to counting methodologies and newly discovered roosts, increases at the Fort are thought to represent population increases or at least increased use of known roosts on the Fort (USFWS 2005).

Fort Huachuca climate and projections

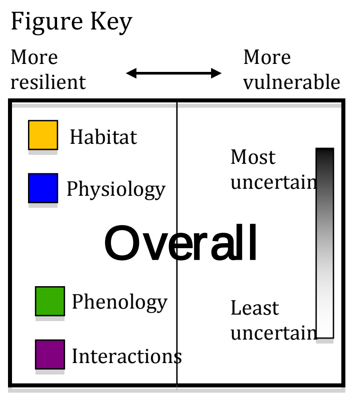
- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir et al. 2008)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith et al. 1984)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects

Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**0.5**	0%
Physiology	**0.7**	33%
Phenology	**0.8**	0%
Interactions	**1.0**	0%
Overall	**3.1**	9%



Other threats and interactions with climate

There are many known threats to this species. Suitable concentrations of food plants and day roosts are considered critical (Fleming 1995). The USFWS five-year review identified illegal border activity, fire, and drought as important threats to roosts or foraging habitats (USFWS 2005). The review further noted that grazing, tequila harvesting, and prescribed fire are probably not substantial threats (USFWS 2005). Urban development, wind farms, and changing fire regimes are additional potential threats that have yet to be addressed as part of recovery planning. Climate change impacts were not specifically addressed in the review.

Roost protection is complicated by disturbance at roost sites. There are also issues with gating cave and mine entrances including gate vandalism and bat avoidance after gating (USFWS 2005). Lesser long-nosed bats may be sensitive to gate construction and configuration. Climate change will also potentially increase roost disturbance by illegal immigrants. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and government programs, both of which predict that drought impacts will be less severe in the U.S. as compared to Mexico (Vásquez-León et al. 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected and, subsequently, an increase in threats to roosts.

Lesser long-nosed bats use clumped concentrations of agaves rather than isolated individuals (Ober and Steidl 2004). Changing climate may allow expansion of agaves into new areas, although it is not expected that increasing temperatures will reduce current agave populations, as they are well suited to survival under dry and hot conditions. Nectar availability, however, may be affected. The greatest threat to bat foraging areas at a landscape level is the likely expansion of invasive grasses and the concurrent increase in fire occurrence with subsequent reduction in agaves and cacti. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann's lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and is becoming increasingly problematic in the Sonoran Desert (Burquez-Montijo et al. 2002). It was, and continues to be, introduced in the Sonoran desert to enhance livestock grazing with almost the entire Sonoran desert ecosystem prone to buffelgrass invasion (Arriaga et al.2004). The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor further conversion to grasslands.

Climate change has the potential to create timing mismatches between species and resources. A number of observations and studies have found there is currently not close synchrony between lesser long-nosed bat arrival in Arizona and New Mexico with the peak of agave flowering (Fleming et al. 2001, Scott 2004). Bat arrival late in agave blooming may allow flexibility in earlier bat arrival although advancement of blooming may be problematic if bat migration cannot advance equally (see Table 1). Observations of timing, however, are limited and generally only over short time periods so it is reasonable to assume there is annual variability of arrival, flowering, and therefore synchrony of these events. Elevational variation at the Fort may lengthen availability of blooming agave so the Fort may be a relatively small but important foraging site (ENRD 2006).

Table 1. Event timing and lesser long-nosed bat (LLNB) populations in northern Mexico, and southern Arizona and New Mexico. Dates of events are listed by month with sources, including recording date and location of observation, noted below.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Saguaro blooming MX			?	1-30	late							
Saguaro blooming AZ/NM				late	1-31	early						
Agave blooming AZ/NM						18-30 late	1-31 1-31	1-31 1-31	1-12 1-30	early		
LLNB presence MX			?	1-30	1-mid?							
LLNB arrival AZ/NM							14-?	24-31 ~9 2-7	1-12			

Sources:
Saguaro blooming MX (1995-1996 Bahia de Kino, Fleming 2001)
Agave blooming MX (Horner 1998)
Saguaro blooming AZ/NM (1997 Organ Pipe, Fleming 2001)
Agave blooming AZ/NM (1997 Chiricahuas, Scott 2004; 1993-1994 southern AZ, Slauson 2000)
LLNB presence MX (1995-1996 Bahia de Kino, Fleming 2001)
LLNB presence NM (1997 Chiricahuas, Scott 2004; 13 year average Chiricahuas, Cockrum 1991; 1999 Huachucas, Ober and Steidl 2004, Beatty 1955)

Timing and the extent of synchronicity in flowering of forage species along migratory routes will affect population sizes and arrival dates in Arizona at least as observed from a single location such as Fort Huachuca. Migratory and non-migratory demes probably make the species more resilient as a whole to variability. More critical to populations is failure of flowering, particularly if synchronous across range. In one study monsoons were found to be generally asynchronous between northern Mexico and the Southwest (Comrie and Glenn 1998), thus adequate resources should be available within some part of the range. Monsoon behavior under current climate projections, however, is unpredictable at this point and past patterns may not extend into the future. Interestingly, there is some evidence that seed set of agaves was higher in the past (Howell and Roth 1981). It is also possible that there was greater synchronicity between bats and flowering in the past.

Part of the U.S. strategy to combat increasing CO_2 levels is to promote alternative energy sources. Wind farms are increasingly being proposed in many areas including the Southwest. Wind turbines are known to kill bats (Arnett et al. 2008), but, to date, there has been no documented mortality for lesser long-nosed bats. Potential for impacts will be, at least in part, related to wind farm locations and their proximity to bat roosts, migratory routes, or foraging areas.

Research Needs

Several areas were identified in the five-year review where information on lesser long-nosed bats is deficient (USFWS 2005). These include bat response to gates and other methods aimed at preventing roost disturbance, wind farm impacts, overall population size, and long term effects of fire on foraging resources.

This assessment of vulnerability to climate change indicates additional research needs. Of particular interest is how fluctuations in flowering timing alter bat migratory behavior and timing of arrival throughout the U.S. range and, in particular, Fort Huachuca. In addition, little is known about climate variability may affect flowering variability particularly across latitudes where the bat occurs and if variables related to flowering influence survival. How warming climate, fire, and expansion of invasive grasses interact would help identify effective management actions. Information is also needed on bat mortality and wind turbines. Research on management options that reduce populations of African grasses and probability of spread is needed.

Management Implications

Because lesser long-nosed bats only spend a portion of the year on Fort Huachuca, factors that affect populations occur largely in other regions and will not be affected by military activities. In addition to local influences, activities in Mexico, where this species winters, will affect populations on the Fort. Fort Huachuca has already undertaken important steps to protect roosting and foraging resources. The Agave Management Plan includes established areas for agave management and a monitoring program. Agave management should include a range of elevations to incur greater resiliency of flowering resources. The potential for increasing impacts from invasive African grasses and increasing fires warrants consideration in management planning and implementation of preventative actions. Management related to post-fire rehabilitation should also include actions that encourage agaves.

Current activity restrictions to protect bats are in place from July 1 to October 31 (ENRD 2006). To protect bats, the Fort also has seasonal closing of mines and caves. Although this time period includes a buffer to known dates of bat presence, anticipated timing changes in bat arrival at Fort Huachuca related to climate change indicates a need to reevaluate time restrictions on activities that may disturb bats in the future.

Habitat: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Lesser long-nosed bats primarily occupy desert scrub habitats (primarily Sonoran, but also Chihuahuan) along with a variety of woodlands, grasslands, and shrublands where food resources are available. Climate projections indicate possible expansion of the Sonoran desert northward as temperatures warm (Weiss and Overpeck 2005). Accordingly, expansion of available habitat for lesser long-nosed bat might be inferred, but there are other important issues to be considered. Expansion will be limited by projected increases in fire frequency and increases in invasive grass species that will both be favored by a warming climate. Some evidence for expansion of suitable areas, but other factors such as fire, invasives, and human developments likely to limit expansion and threaten current range.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Non-breeding areas will likely be reduced with decreases in Sonoran desert habitats to the south in Mexico predicted by temperature and precipitation projections in addition to the interacting effects of invasive grasses and fire occurrence. Sonoran desert is projected to decline in the southern portions of the range (Weiss and Overpeck 2005). Active conversion of Sonoran desert to grasslands and projected increases in fires make further loss of habitat area likely.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Several types of roosts are used: day roosts, maternity roosts, bachelor roosts, and temporary night roosts. Roosts are often in caves or abandoned mines. Individuals require multiple roost types at different locations. A large maternity roost is located approximately 240 km (150 miles) from the Fort in Organ Pipe Cactus National Monument (ENRD 2006). Maternity roosts do not occur on Fort Huachuca. Use roosts of variable types and microclimates. Climate unlikely to affect availability of suitable roosts.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Roosts are often in caves or abandoned mines. Individuals require multiple roost types at different locations. Important day and night roosts have been identified on Fort Huachuca, although there are likely unknown roost sites as well (ENRD 2006). Thought to use roosts with a variety of microclimates so, it is unlikely that warmer temperatures will decrease roost availability.	**0**

Habitat: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Warmer maternity caves associated with better development of young (Arends et al. 1995). May benefit from rising temperatures.	**-1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Migratory and highly mobile moving over large areas to feed.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	For Arizona, this species is a long distance migrant. Some populations remain resident in Mexico. Migratory behavior is thought to take advantage of periodic resources (USFWS 1995). Male and females follow progressive flowering of columnar cactus and paniculate agaves. Although highly mobile, they avoid crossing high density urban housing (USFWS 2005).	**1**

Physiology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Lesser long-nosed bats have a lower critical temperature of 30.5°C and generally seek warm conditions (Fleming et al. 1998). They often roost colonially in caves that trap metabolic heat, but have been found in a variety of different roost conditions (USFWS 1995). Migratory females give birth in Arizona and warmer maternity roosts may increase growth rates of the young (Arends et al. 1995). Leave U.S. because of cold winter conditions and seem well suited to desert conditions with a fairly high lower critical temperature. While projected changes are not expected to exceed physiological thresholds, they may instead reduce cold periods, which are unsuitable.	**-1**

Physiology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Heavy rainfall events, which are expected to increase, are associated with mortality in some species- documented at Carlsbad Caverns. Flood risk at Fort Huachuca roosts is unknown.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	They can fly long distances between roosts and foraging sites (from 50-100 km, USFWS 1995). Although distance from roosts to foraging areas is considered an important component of energy expenditure, lesser long-nosed bats have also been found to be efficient fliers and well adapted to performing long daily commutes (Horner et al. 1998). Active at night. Rest part of the night in night roosts, but no information on limitations to foraging on hot nights. Although distance between roost sites and foraging locations may be affected, there is no anticipated effect, because apparently do not need to expend large amounts of energy to forage at distant locations.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Migratory behavior seems to be variable with both migratory and sedentary strategies that may be an adaptation to highly variable flowering resources (Rojas-Martinez et al. 1999). Occurrence of migratory and non-migratory demes related to resource availability and likely helpful with fluctuating resources. All individuals at Fort Huachuca, however, are migratory so these populations do not possess this alternative and plasticity in behavior within demes is unknown.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Do not hibernate. Probably initiates migration based on flowering resources, but may also be related to progress of pregnancy in females. No direct moisture or temperature cues known.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Migratory females arrive in Arizona pregnant and give birth to one young that can fly at about 4 weeks. Birth is not highly synchronous among individuals at the same maternity cave with pregnant females co-occurring with females with young that are ready to fly (USFWS 1995). Females that do not migrate give birth in winter in Mexico (USFWS 2005). Migration and breeding is tied to flowering timing, which is likely to be altered by changes in temperature and precipitation.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Lesser long-nosed bats are present April to November in Arizona, although this seems to vary by year. Movements coincide with blooming (cactus in the spring, agave in the summer). Likely that this species' movements are directly related to presence of nectar resources, thus has the potential to respond quickly to changes.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Lesser long-nosed bats are adapted to feed on nectar and pollen of various columnar cactus and paniculate agave species. They are able to switch between various cactus and agave species when flowering of one species fails and also may eat insects, fruits, and have been observed to use hummingbird feeders (USFWS 2005). Northern migrants eat almost exclusively CAM (Crassulacean Acid Metabolism) plants (agaves and cactus). Because of their ability to open their stomates at night, CAM plants are well adapted to dry conditions. In Mexico, lesser long-nosed bats are known to feed on C_3 plants (most shrubs and forbs) as well (Fleming et al. 1993). Agaves on Fort Huachuca are primarily Palmer's agave (*Agave palmeri*) with some Parry's agave (*Agave parryi*). Mostly dependent on agave at Fort Huachuca. These CAM plants are resilient to dry conditions, but flowering and thus nectar availability generally decreases under dry conditions. In addition, more variable rainfall may increase variability in flowering.	**1**
2. Predators	Are important predator populations expected to change?	Few incidences of predation have been documented and predators were various. No avoidance of activity during full moons suggests predation pressure while foraging is not strong (USFWS 1995). Potentially large impacts of single predators at small roosts, but overall probably has little impact on populations.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	They are an important, but not exclusive, pollinator and seed disperser for these plants. Some researchers cite close association and bat adaptations in paniculate agaves and columnar cactus as evidence for a tight mutualistic relationship, but others have noted that this relationship is likely not as strong in the southwestern US and northwest Mexico as in areas where nectar-feeding bats occur year-round (Fleming et al. 2001). Foraging plant populations expected to survive warmer temperatures and reduced rainfall.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Rabies has been found in this species in Mexico and, while it can result in bat mortality, rabies is not common and generally not considered to be a significant threat to bat populations (Gillette and Kimbrough 1970). Another emerging bat disease is white nose syndrome, which has been killing large numbers of roosting bats in northeastern North America. So far, it appears this disease only threatens hibernating species and is associated with cold conditions (Blehert et al. 2008). Lesser long-nosed bats have neither of these risk factors.	**0**

Biotic Interactions: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)

Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Competitors	Are populations of important competing species expected to change?	Lesser long-nosed bats roost with a variety of other bats in Mexico (Arita 1993) and do not appear to segregate from other bat species at roosts. Other nocturnal nectarivores that exploit these nectar resources are much smaller (e.g., moths, birds) so probably little competition. Could be competition with other nectarivorous bats, but Mexican long-tongued bats probably exploits additional flower resources with its longer tongue. Expected to be similarly affected by climate change.	**0**

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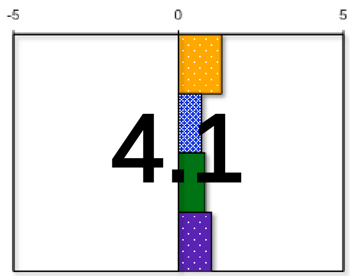


Mexican Long-tongued Bat (*Choeronycteris mexicana*)

SUMMARY

Populations of Mexican long-tongued bats that currently occur in Arizona are females that migrate to maternity colonies. Like the lesser-long nosed bat, this species is expected to be vulnerable to changes in temperatures that will affect habitats and, in particular, flowering cacti and agave. Conversely, warmer winters will make conditions more favorable to year round presence in the future. Fire, fuels, and invasive grass species management will be critical to this species.

Introduction

Mexican long-tongued bat is a USFWS species of concern, Forest Service sensitive, and a species of greatest conservation need, Tier 1C, in Arizona SWAP (2010). It is also designated as a species at risk (SWESA 2006). Many aspects of this species' biology are not well known, but populations may be declining in Arizona (BISON-M). Individuals recorded in Arizona have been mostly females, but there are a few records of males in the U.S. as well (Balin 2009). These populations are largely maternal roosting colonies, although it is rare to see more than 25 individuals together (Joaquín et al., 1987). Similar in ecology to the lesser long-nosed bat, this species is nectivarous and migrates from U.S. locations to Mexico where it is generally resident year round. This species is present at Fort Huachuca.

Fort Huachuca climate and projections

- Annual increase in temperature 2.5-4.5°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevilla et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Reductions in Madrean woodlands (Rehfeldt et al. 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin et al. 2007)

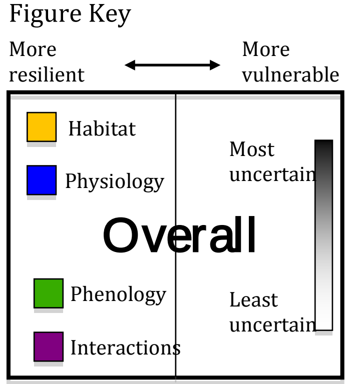
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith et al. 1984)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**1.3**	14%
Physiology	**0.7**	67%
Phenology	**0.8**	0%
Interactions	**1.0**	20%
Overall	**4.1**	27%

Figure Key



Other threats and interactions with climate
Many historic locations for this species remain occupied in Arizona including various locations in the Huachuca Mountains (Cryan and Bogan 2003). Thus, although rare, populations in Arizona may be relatively stable. Mexican long-tongued bats, however, are threatened by a number of factors that we expect to be exacerbated by future climate change.

Like most bats, Mexican long-tongued bats are vulnerable to roost disturbance (NatureServe 2009). Roost protection is complicated by disturbance at roost sites. It is unknown if they are sensitive to gate construction like lesser long-nosed bats. Climate change will potentially increase roost disturbance by illegal immigrants. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and government programs, both of which predict that drought impacts will be less severe in the U.S. as compared to Mexico (Vásquez-León et al. 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected and, subsequently, an increase in threats to roosts.

The greatest threat to bat foraging areas at a landscape level is the likely expansion of invasive grasses and the concurrent increase in fire occurrence with subsequent reduction in agaves and cacti. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann's lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and is becoming increasingly problematic in the Sonoran Desert. It was, and continues to be, introduced in the Sonoran desert to enhance livestock grazing with almost the entire Sonoran desert ecosystem prone to buffelgrass invasion (Arriaga et al.2004). Fires occur more frequently in the dry biomass created and burning encourages more buffelgrass. The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor grasses at the expense of species prone to fire mortality such as cacti and agaves.

Research Needs

Critical resource requirements are not well known in this species making effective management difficult. We found little information on the specific requirements for roosting locations, which will be important to identifying critical roost resources. Important foraging plants are also not well known in this species although it is assumed that they may use a broader selection than lesser long-nosed bats. More study is needed to understand flexible migratory behaviors in this species. Depending on how this flexibility occurs in populations or individuals, changes in migration might be expected to occur regularly resulting in observed population fluctuations at isolated locations.

Management Implications

The potential for increasing impacts from invasive African grasses and increasing fires warrants consideration in management planning and implementation of preventative actions. Management related to post-fire rehabilitation should also include actions that encourage agaves and cacti in suitable areas.

Fort Huachuca has taken a number of measures to protect bats including protecting agave in Agave Management Areas and seasonal closure of mines and caves. Although these primarily target the endangered lesser long-nosed bat, the Mexican long-tongued bat will also benefit. Timing changes in bat arrival and presence at Fort Huachuca related to climate change indicates a need to reevaluate time restrictions on activities that may disturb bats in the future. In addition, identification and monitoring of suitable caves or mines is warranted as conditions become more favorable for these bats.

Habitat: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In the U.S., Mexican long-tongued bats breed along the border region with Mexico. In Arizona, this species to inhabit primarily the oak-pine belt at elevations ranging from 4000 to 6000 ft as well as saguaro-paloverde desertscrub (BISON-M). Additionally, they are often associated with Madrean evergreen woodlands and semidesert grasslands with agave species in this region (Cryan and Bogan 2003). Increasing fires and invasive grasses will likely reduce pine-oak habitats along with upward elevational shifts.	**1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Individuals that breed in the U.S. are mostly, if not all, females and, after breeding, migrate to Mexico for the winter (Joaquín et al. 1987, BISON-M). Central Mexico vegetation associations include desert scrub and mixed pine-oak forest (NatureServe, 2009). Also expected to be exposed to increased fires and invasive grasses.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Maternity roosts are required and are usually in caves or abandoned mines (NatureServe 2009). Availability not expected to change.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Day and night roosts are also required for non-breeding individuals (BISON-M 2009). Roosts include buildings, rock fissures, and caves (NatureServe 2009). Availability not expected to change.	**0**

Habitat: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	None known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile although males and females have different dispersal patterns.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Populations in Arizona are migratory.	**1**

Physiology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Range extends from southern California, Arizona and SW New Mexico southward into central Mexico and into Central America (Joaquín et al., 1987). This species is limited in occupation of Arizona habitats because of cold limitations. Warmer temperatures may create more favorable conditions.	**-1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	Fire or other extreme weather is unlikely to result in direct mortality. Roosts are somewhat protected from disturbance though there have been incidences of flooding of roosts and bat mortality in some species. Heavy rainfall events, which are expected to increase, are associated with mortality in some species and have been documented at Carlsbad Caverns. Flood risk at Barry M. Goldwater roosts is unknown.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Active at night. No information on limitations to foraging on hot nights. Rest part of the night in night roosts. Activity periods will probably not be reduced or increased.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Seems to have somewhat flexible migration. Not known if this flexibility is possessed within individuals or within certain populations. All bats in Arizona are currently migratory and it is not known if they would not migrate should flowering fail. Possible, but too little information.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Cues are likely a combination of internal and external signals. Do not hibernate.	**0**

Phenology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	Births in Arizona occur between mid-June and early July (BISON-M) and may be timed to peak flowering. Earlier flowering has been documented in many Sonoran desert plant species including columnar cacti and agave (Bustamante and Búrquez, 2008).	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	These bats follow the sequential flowering of agave, saguaro, ocotillo, palo verde and prickly pear cactus (Fleming 1988). Migrations are described as following the sequential flowering of various cacti species (Fleming 1988).	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Consume nectar and pollen from flowering plants, such as agaves and saguaro, and may supplement their diet with cactus fruit and insects (BISON-M 2009). Mexican long-tongued bats may be able to feed on a greater variety of flowers than lesser long-nosed bats because of their longer tongues (BISON-M 2009). In Arizona, large numbers of bats are thought to rely on hummingbird feeders before and after agave flowering season (BISON-M 2009). Flowering and thus nectar availability generally decreases under dry conditions. In addition, more variable rainfall may increase variability in flowering.	**1**

Biotic Interactions: Mexican Long-tongued Bat (*Choeronycteris mexicana*)

Trait/ Quality	Question	Background Info & Explanation of Score	Points
2. Predators	Are important predator populations expected to change?	Limited information on predators, but known to be preyed upon by owls (Joaquín et al., 1987). Predation rates not likely to change.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Rabies has been found in this species in Mexico and, while it can result in bat mortality, rabies is not common and generally not considered to be a significant threat to bat populations (Gillette and Kimbrough 1970). Another emerging bat disease is white nose syndrome, which has been killing large numbers of roosting bats in northeastern North America. So far, it appears this disease only threatens hibernating species and is associated with cold conditions (Blehert et al. 2008). Mexican long-tongued bats have neither of these risk factors.	**0**
5. Competitors	Are populations of important competing species expected to change?	Other nocturnal nectarivores that exploit these nectar resources are much smaller (e.g., moths, birds) so probably little competition. Could be competition with other bats, but lesser long-nosed bats probably exploits additional flower resources with its longer tongue. Expected to be similarly affected by climate change.	**0**

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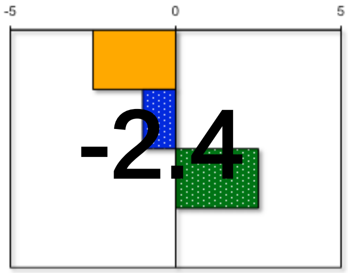


Black-tailed Prairie Dog (*Cynomys ludovicianus*)

SUMMARY

Potential habitat exists on Fort Huachuca for this keystone species. Plague is considered to be the greatest current impact and prevalence will likely be altered by climate change, but ultimate outcome for mortality rate is unclear. Based on a broad suite of traits, we predict that prairie dog response to climate change will be somewhat resilient overall, thus population dynamics will largely depend on other factors. Potential for dispersal to Fort Huachuca should be evaluated.

Introduction

USFWS found that listing of the black-tailed prairie dog as threatened or endangered was unwarranted and that the proposed Arizona black-tailed prairie dog (*Cynomys ludovicianus arizonensis*) is not a distinct population or subspecies (Dec. 2009). Other analyses identify the *arizonenis* populations as a unique subspecies (BISON-M 2009). In 1960, the black-tailed prairie dog was considered extirpated in Arizona (ENRD 2006), but it was reintroduced to Arizona in 2008 via translocations. Reintroductions in and adjacent to Las Cienegas National Conservation Area began in 2008. USFWS included climate change as a potential threat when considering listing status and concluded that climate change does not threaten the species with extinction in the foreseeable future. Black-tailed prairie dogs are a species of greatest conservation need, Tier 1A, in Arizona SWAP (AGFD 2006) and a species at risk (SWESA 2006). Fort Huachuca has potential habitat for this species (ENRD 2006).

Fort Huachuca climate and projections

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)
- Riparian habitats decline (Stromberg et al. 2006, Serrat-Capdevila et al. 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

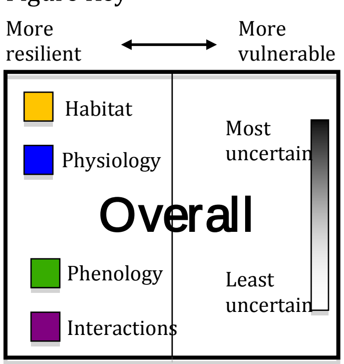
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith et al. 1984)

A detailed review of projections is in the projections section of the main document (Page 8).

Predicted climate change effects
Based on RMRS v.2.0. Score of 0 indicates neutral effect of climate change, while positive scores indicate vulnerability and negative scores, resilience. Scores in each category range from -5 to 5 and overall from -20 to 20 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-2.5**	0%
Physiology	**-1.0**	33%
Phenology	**2.5**	25%
Interactions	**0.0**	40%
Overall	**-2.4**	23%

Figure Key



Other threats and interactions with climate
Prairie dogs have been widely poisoned and shot for interference with livestock, but sylvatic plague is considered to be the most important current impact (USFWS 2009). Spread of plague could be exacerbated by climate change (USFWS 2009). Plague is enhanced by cooler summer temperatures and by increased precipitation. Consequently, the extent to which plague may shift due to climate change versus expand or contract is supposition (USFWS 2009). Extinctions generally follow ENSO events, but there is complex dynamics with colony metapopulation dynamics (Stapp et al. 2004). Warmer and wetter winters may contribute to flea vector populations

and also winter survival in prairie dogs, thus increasing the chances of transmission (Stapp et al. 2004). In the southwest, human plague outbreaks are higher during periods of higher rainfall, but decrease with high summer temperatures (Parmenter et al. 1999).

Population declines in the Southwest have partly been attributed to the conversion of grasslands to shrublands (USFWS 2009). Climate change will have important interactions with grass and shrub species, and may favor grasses in the Southwest. Incidence of fires and current vegetation will also be influential in future vegetation projections.

Research Needs
More complex analysis is needed to evaluate how plague and climate change interact with particular attention to regional differences. Plague interactions in Arizona may be quite different from those in the Midwest. In general, most studies on this species are from cooler climates, therefore more specific information on habitat and population dynamics for the Southwest are needed.

Management Implications
This species is not of current management concern for Fort Huachuca. We expect that climate change will not greatly impact this species. If other impacts are low enough to allow reintroduced populations to increase, there could be expansion of prairie dog towns. Dispersal onto Fort Huachuca will depend on a number of factors including dispersal barriers and land ownership. An evaluation of this potential would be useful in determining if prairie dogs need to be included in future planning documents.

Habitat: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and Distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in grasslands with flat or gently sloped topography (USWFS 2009). In Arizona, occupies desert grasslands (BISON-M 2009). Desert grasslands in southwestern U.S. are probably encouraged by warmer temperatures and increasing fires.	**-1**
2. Area and Distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Burrows are required and created by prairie dogs. No change in suitable soils for burrowing.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Same as above.	**0**

Habitat: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Shorter and less dense vegetation is generally associated with greater predator avoidance in prairie dogs. Although vegetation height will be more variable with increasing variability in rainfall, prairie dogs also actively clip vegetation. No effect anticipated.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Known to disperse long distances to establish new colonies although most dispersal is between colonies. Dispersal rates are considered generally low and may contribute to interpopulation genetic variation (Chesser 1983). May expand foraging area during drought (USFWS 2009). Dispersal abilities can likely keep up with habitat shifts.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Tolerant of a wide variety of conditions including hot daytime temperatures.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**

Physiology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Exposure to weather-related disturbance	Are disturbance events (e.g. severe storms, fires, floods) that affect survival or reproduction expected to change?	None known and generally avoid areas prone to flooding. Fires probably do not result in direct mortality. Drought not thought to be a limiting factor (USFWS 2009).	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Less active in summer than winter (Tileston and Lechleitner 1966), but no known effect on fitness. Although this species may avoid the hottest parts of the day in burrows, no information that activity periods are limited.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Facultative torpor has been observed in this species and was associated with sudden drops in ambient temperatures, but not precipitation (Lehmer et al. 2001). Colonial habits and flexibility may help populations cope with resource fluctuations.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g. hibernation, migration, breeding)?	Cues are likely a combination of internal and external factors. Arizona populations do not go through hibernation.	**0**

Phenology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g. food, breeding sites) that are expected to change?	In Colorado, young were born in late March through early April (Tileston and Lechleitner 1966). Breeding in the spring may be timed with new growth of vegetation. Timing of new growth is likely to change.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Cues not distant from resources.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One litter per year.	**1**

Biotic Interactions: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats grasses and forbs. Also consume roots (Tileston and Lechleitner 1966). Prefers grass species in desert grasslands (BISON-M 2009). Food preferences vary with phenology and diet is considered specialized opportunist (USFWS 1989). Seeds, woody stems, and cactus are eaten in winter (USFWS 1989). Variety will likely result in no overall change in quantity.	**0**

Biotic Interactions: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Predators	Are important predator populations expected to change?	Large number of predator species. Major predators in Arizona not known. Unlikely to change overall.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Considered a keystone species but is not dependent on presence of other species. Interactions with other prairie dogs also important. Colonial behavior aids predator detection, rearing of young, and parasite removal (see Physiology Question 5). No changes in colony size predicted. No dependence on other species.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Plague is a major source of mortality and can also be transmitted through fleas during grooming and other contact. Complex interactions with climate and metapopulations. Could increase with warmer wetter winters, but precipitation is not expected to increase on average and hot summers are associated with decreased incidence of plague. Needs more complex analysis. No change projected.	**0**
5. Competitors	Are populations of important competing species expected to change?	Domestic livestock are popularly considered competitors, but livestock grazing may also favor prairie dogs by reducing vegetation height and increasing predator detection (USFWS 2009). Grazing interactions with domestic or native species is limited on Fort Huachuca.	**0**

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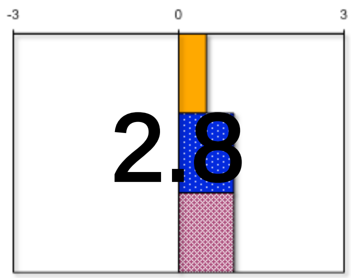


Huachuca Water Umbel
(*Lilaeopsis schaffneriana* var. *recurva*)

SUMMARY

The Huachuca water umbel is present only at locations that remain wet year round, thus is prone to future population declines as evaporation increases and precipitation patterns are altered. Flooding is important for dispersal, but also can threaten established populations. Similarly fires can increase sedimentation, but can also open canopy and increase run-off. Some intermediate level of disturbance is likely optimal for this species, although optimal levels may change as disturbance regimes are altered. Management related to hydrology and fire will be important with the biggest challenge being the retention of water in occupied wetlands.

Introduction

The Huachuca water umbel is a federally endangered plant that has also been known as *Lilaeopsis recurva*. It is also designated as sensitive by the US Forest Service and highly safeguarded under Arizona Native Plant Law (ENRD 2006). Huachuca water umbel occupies Garden Canyon and tributaries (ENRD 2006). Portions of this habitat are designated as critical (USFWS 1999). Some of these populations were identified after 1995 along with several populations outside of Fort Huachuca (ENRD 2006). It also occurs outside of the U.S. in northern Sonora, Mexico.

Fort Huachuca Climate Projections Used for Assessment

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)

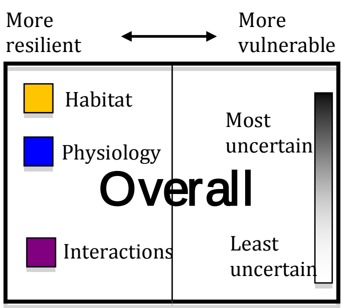
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted Climate Change Vulnerability

Based on RMRS Plants v.1.0. Score of 0 indicates neutral effect of climate change while positive scores indicate vulnerability and negative score resilience. Scores in each category range from -3 to 3 and overall from -10 to 10 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**0.5**	0%
Physiology	**1.0**	33%
Interactions	**1.0**	66%
Overall	**2.8**	30%

Figure Key



Other Threats and Interactions with Climate Change
The primary threat to the Huachuca water umbel is loss of water and degradation of wetlands (USFWS 1999). This threat will be intensified under warmer temperatures. High severity wildfires, which are projected to increase, are likely to increase sedimentation, which negatively impacts habitat. Other sources of erosion such as recreation and flooding are also considered detrimental (ENRD 2006). Flooding, however, is important for dispersal, thus the best habitats include locations that are both prone to floods and those that are refugia from floods (USFWS 1999). Irregular flood events may be beneficial to sustaining populations, although this will depend on a number of factors including topography and flood intensity. This species should be resilient to changes in timing of floods.

Flowering may be reduced where cover of competing species is high, possibly from reduced light levels (Titus and Titus 2008). More open habitats, however, can dry out faster (Titus and Titus 2008) and dispersal seems to mostly be associated with flooding.

Various activities are considered potentially detrimental to populations. The most important are those that reduce water for wetland habitats or otherwise alter or degrade wetland habitats or hydrology. Channelization also encourages unfavorable flooding (Titus and Titus 2008). Other potential threats include catastrophic fires, livestock grazing, logging, military activities, and recreation. Low to moderate severity fires may maintain suitable habitats by reducing competing canopy (Titus and Titus 2008), but, as noted above, can also increase sedimentation. Fires may be additionally beneficial as they can increase run-off and water inputs to streams, at least in the short term. Favorable environmental conditions of more closed canopy will likely increase in importance with climate change.

Research Needs

An assessment of future flood risk and potential impacts for Fort Huachuca would aid management of this species, because this species is associated with specific hydrological conditions and dispersal depends on flooding.

Management Implications

Response to climate change in this species is difficult to project because of the species' complex relationship with flooding and other processes that remove vegetation such as fire. Some balance of these disturbances is likely optimal. Management that affects hydrology and fire regimes will need to consider both the positive and negative influence of these activities. Planning should be in place for locations that are expected to dry to the point they are no longer suitable for this species. Planning that considers inclusion of translocation may be warranted.

Habitat: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Increased droughts and warming.	Is this species associated with wetlands, riparian areas, or other mesic environments expected to decline?	Occupies cienegas in a variety of arid habitats including grasslands, desert scrub, oak woodlands, and coniferous forests (ENRD). Locations of occurrence have permanent surface water or are seasonally saturated and where not prone to flooding (USFWS 1999). Current elevational limits are 855m to 2100m (2800 to 7000 feet) (Titus and Titus 2008).	**1**
2. Habitat elements	Does this species require specialized microsites?	Also needs refugia from flooding that are also not prone to drying and a moderately open canopy (USFWS 1999). Flooding will likely be more irregular and intense while fires will become more frequent. In addition, wetland areas are limited in the region.	**1**
3 Ability to colonize new areas	What is this species dispersal ability?	Perennial species with creeping rhizomes. Reproduction can be sexual through flowers, but most is through asexual through spread of rhizomes (USFWS 1999). Dispersal can also occur through rooting of dislodged clumps that are swept downstream (USFWS 1999). Seeds are buoyant and likely disperse by water (Titus and Titus 2008).	**-1**
5. Seedling conditions	Do seedlings require different conditions from mature individuals (shade, moisture, fires, nurse plants, etc)?	Seedling conditions similar to mature plants	**0**

Physiology: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Exposure to disturbance	Are disturbance events that result in direct mortality or reproductive failure expected to change?	Wildfires are likely to increase sedimentation and negatively impact habitat although an open canopy may increase light levels. Other sources of erosion such as recreation and flooding are also considered detrimental (ENRD). Locations of occurrence have permanent surface water or are seasonally saturated and where not prone to flooding (USFWS 1999). Flooding can, however, aid dispersal. Overall, increases in drought, flooding, and wildfires will have at least some detrimental impacts.	**1**
2. Adaptations to survive water limitations	Does this species possess adaptations to increase survival during droughts (i.e., waxy leaves, water storage, cavitation, drought deciduous)?	Leaves may not grow from rhizomes during droughts, saving energy and exposure. In addition, seeds have some ability to survive droughts (Titus and Titus 2008).	**-1**
3. Photosynthetic pathway	Which photosynthetic pathway does this species use?	C3	**1**

Interactions: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Pollination	What is the pollination vector?	Insect.	**1**
2. Disease	Any known diseases/parasites that result in mass mortality related to temperature or precipitation?	No.	**0**
3. Competitors	Are populations of important competing species expected to change?	Nonnative plants can limit occurrences (USFWS 1999), although no information on problematic species. Interaction is subject to changes dependent on species and disturbance regimes. Flowering may be reduced where cover of competing species is high possibly from reduced light levels (Titus and Titus 2008). No predictable change based on various species and interactions.	**0**

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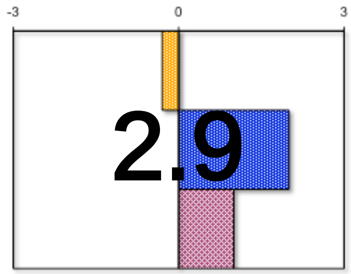


Lemmon Fleabane
(*Erigeron lemmonii*)

SUMMARY

Some additional vulnerability is predicted for this species with future climate change, but this is based on the limited information available for this species. Its presence in a single location alone is enough to increase vulnerability to any impact. Recruitment in particular may be vulnerable to changes in precipitation. Identification of other populations will be important and any transplanting needs to consider future conditions of potential sites.

Introduction

Lemmon fleabane is a candidate for listing as a federally endangered or threatened species. The only known location for this species is Scheelite Canyon on Fort Huachuca (USFWS 2001).

Fort Huachuca Climate Projections Used for Assessment

- Annual increase in temperature 2.2°C or 4°F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell et al. 2002)
- More droughts and intense storms (Seager et al. 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager et al. 2007)

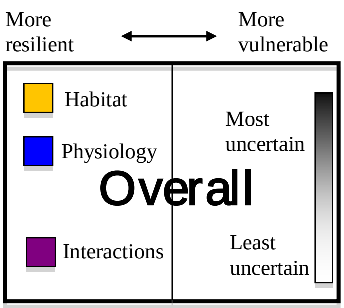
A detailed review of projections is in the projections section of the main document (Page 8).

Predicted Climate Change Vulnerability

Based on RMRS Plants v.1.0. Score of 0 indicates neutral effect of climate change while positive scores indicate vulnerability and negative score resilience. Scores in each category range from -3 to 3 and overall from -10 to 10 (note: overall is not the sum of category scores). Score details for this species appear at the end of this document.

VULNERABILITY		
	SCORE	Uncertainty
Habitat	**-0.3**	50%
Physiology	**2.0**	66%
Interactions	**1.0**	66%
Overall	**2.9**	60%

Figure Key



Other Threats and Interactions with Climate Change

Lemmon fleabane is highly prone to extinction as it is only known to occur at one location. The current location is relatively invulnerable to human impacts, but is exposed to other impacts that may or may not be related to climate change. Its specialized habits, however, may help protect it from disturbance. Occurrence in shady habitats may reduce exposure to higher temperatures to some extent, but tolerances are not known. Hairy leaves will likely help protect them from increased solar radiation. Flowering occurs in August and October and, thus, may depend on summer rainfall (USFWS 2001). Flowering and recruitment are likely vulnerable to projected increases in rainfall variability and reduction in water availability.

Research Needs

Research needs cover almost all aspects of this species' biology. Little published information on any topic was found on this species making assessment or management difficult.

Management Implications

Potential habitats should be evaluated and surveys conducted to identify additional populations of this species. Possible threats to the current population should be evaluated including erosion and flooding. This species may be a good candidate for transplantation or propagation, but future climate will need to be considered for any transplant locations. Monitoring will be important and should examine recruitment to assure sustainable populations.

Habitat: Lemmon Fleabane (*Erigeron lemmonii*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Increased droughts and warming.	Is this species associated with wetlands, riparian areas, or other mesic environments expected to decline?	Grows on vertical cliffs at 1900 – 2200 m (USFWS 2001). Not mesic.	**0**
2. Habitat elements	Does this species require specialized microsites?	Grows in crevices on vertical faces of boulders (USFWS 2001).	**1**
3 Ability to colonize new areas	What is this species dispersal ability?	Wind dispersal?	**-1**
5. Seedling conditions	Do seedlings require different conditions from mature individuals (shade, moisture, fires, nurse plants, etc)?	Not known.	**0**

Physiology: Lemmon Fleabane (*Erigeron lemmonii*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Exposure to disturbance	Are disturbance events that result in direct mortality or reproductive failure expected to change?	No known response to disturbance. Presumably protected from fires on vertical cliffs. May be prone to erosion following intense rainfall, but may also be minimal in crevices of rocky cliffs of Scheelite Canyon. Rock slides are not expected to change with climate.	**0**
2. Adaptations to survive water limitations	Does this species possess adaptations to increase survival during droughts (i.e., waxy leaves, water storage, cavitation, drought deciduous)?	None known.	**1**
3. Photosynthetic pathway	Which photosynthetic pathway does this species use?	C3	**1**

Interactions: Lemmon Fleabane (*Erigeron lemmonii*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Pollination	What is the pollination vector?	Presumably insect pollinated.	**1**

Interactions: Lemmon Fleabane (*Erigeron lemmonii*)			
Trait/ Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Disease	Any known diseases/parasites that result in mass mortality related to temperature or precipitation?	None known.	**0**
3. Competitors	Are populations of important competing species expected to change?	None known, but likely limited in specialized habitats.	**0**

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